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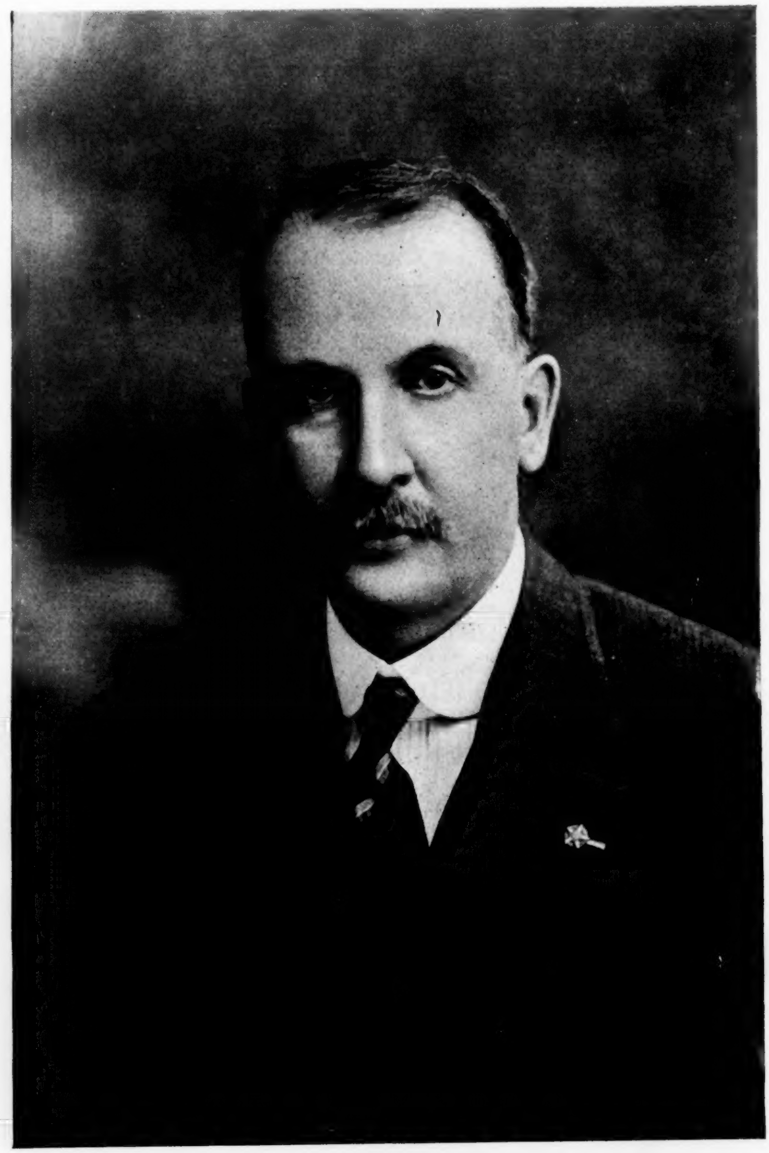

Colonel Edward Bartow, President, 1921–1922.

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THE ROMANCE OF WATER STORAGE[1]

By George A. Johnson[2]

Thirty short years ago this country was the victim of gross ignorance respecting the disease-producing potentialities of public water supplies. Typhoid fever was rampant, and in a single decade millions of persons grievously suffered and hundreds of thousands died in consequence of disease brought to them by the unostentatious agency of impure water. Incidentally, in this ten-year period there passed beyond all recovery the stupendous sum total of $2,625,000,000 in vital capital due to typhoid fever alone.

In the space of this single decade one in every 35 persons in the United States contracted typhoid fever, but the lay public saw nothing particularly alarming in that, reasoning that about so many people every so often were destined to enter the realm of darkness by reason of various and sundry disorders, of which "bowel trouble" was one. But a few men, more given to serious thinking than their fellows, and more skilled in the arts and sciences, took counsel among themselves and decided that the existing state of affairs was entirely unseemly. It was pointed out that in our twenty biggest cities alone 36,000 souls were being hurried toward eternity each year because of typhoid fever, and in that space quite one-tenth of these actually arrived at "the undiscovered country from whose bourn

[1] Read at the Cleveland Convention, June 8, 1921. Further discussion is desired and should be sent to the Editor.

[2] Consulting Engineer, 150 Nassau Street, New York.

no traveller returns." It was hinted that the vast bulk of this annual human expedition might have received its tickets from polluted water supplies. The question was, what should be done to stop this involuntary permutation of human life into the intangible essence of ethereal similitude?

Sundry remedies were suggested.[3] In the opinion of some all water used for drinking should be boiled; in that of others that it should be distilled; still others held that it should be treated in domestic filters; while another group advocated the filtration of all water used for the public supply of all needs.

Still another faction submitted that initial prevention was the infallible cure for this desperate state of affairs; that quite the only thing to do was definitely to stop the pollution of all public waters. A branch of this element not only was disposed to prevent all initial pollution, but for fear somebody might slip in a few disease germs while the watch was asleep desired that the water should be allowed to impound in large reservoirs before use, that such incidental living contamination as might get by the prevention squad would thus be afforded time to repine and die of old age and discouragement through unrequited ambition.

Suffice it to say that of the 22,800,000 people supplied in 1890 from 1,878 public water works, less than 1.5 per cent were furnished filtered water. The cholera epidemic in Hamburg had not yet occured to teach its striking lesson. The classic investigations at the Lawrence Experiment Station had only just gotten well under way. Frankland's invaluable studies on the removal of bacteria by water filters had not yet been developed on a decisive scale, and the scientific mind was still groping about in the dark for the push button which would force the illumination of the abysmal darkness surrounding the proposition of how to make impure water pure. The only thing clearly recognized was the precept as old as the ages, namely, that the Mosaic Law had merit.

In the decade 1890–1900 things began to happen. Frankland was on the eve of proving that filters remove bacteria from water. The Hamburg epidemic proved that filtration of grossly polluted water would eliminate the disease germs it contained. The studies at Lawrence, Providence, Louisville, Pittsburgh and Cincinnati taught the craft how to purify water by practical means. About

[3] See also Proceedings of the Eighth International Congress of Hygiene and Demography, Buda-Pest, September, 1894.

1,500,000 more people were added to the total of those whose public water supplies were filtered, raising the grand total in 1900 to about 2.4 per cent of the total population of the United States. The main accomplishment, however, was the development of precise knowledge of the menace in impure water and practical methods of correction.

The decade 1900–1910 was an era of accomplishment. Based upon the knowledge acquired in the previous decade, water filter plants were built in scores of cities, and the filtered water population increased from the 2.4 per cent of the previous decade to nearly 12 per cent. One in every four persons representing the urban population of the United States was being supplied with filtered water in 1910. Moreover, in the ten years ending 1910, the typhoid fever death rate in the registration cities of the United States fell from 36 to 22 per 100,000 population living. The good work has continued through the decade just ended. Some 25,000,000 people are now supplied with filtered water, and the typhoid fever death rate in the registration cities has fallen to an average of 10 per 100,000 population living.

Strange to say, however, at this late and more enlightened day there exists an element among public sanitarians the leaders of which still cling to the idea that it is permissible to rely upon primary lines of defense against water-borne disease, such as depopulation and sanitary patrol of watersheds and storage of surface waters in impounding reservoirs. This element is not insensible to the additional and complete protection afforded by artificial processes of water purification, but for assumed reasons which are utterly beyond the ken of the author they offer vague arguments against water filtration and sterilization "except where necessary."

The filtration or sterilization of all surface water supplies is always advisable and in the strictest sense is always necessary. Certainly the cost attendant upon the utilization of such definite lines of defense against water-borne disease is justifiable because of the assurance of water purity they afford. Minimization of initial pollution is splendid water supply sanitation; storage is a link, however weak, in the preventive chain; but filtration and sterilization give the finishing touch, and with or without the aid of the primary measures of prevention just referred to they afford the protection against water-borne disease to which every American citizen is entitled. The dice of God are always loaded, and it is just as well

to be prepared for the worst. This aphorism applies equally well to water supply practice and all other lines of human endeavor.

So much for a brief résumé of the subject of water supply sanitation. The muttons of our repast have not yet been set upon the table, nor particularly mentioned except in the bill of fare, so to speak. To these we now come with the full expectation of serving them with a sometime vinegary sauce of truth; and it is hoped that the author may be pardoned for stating truths in a paper which he has frankly labelled "The Romance of Water Storage."

The impossibility of preventing absolutely the dangerous pollution of surface waters. There are certain standard methods which, individually or combined, usually are followed in attempts to preserve the pristine hygienic purity of surface water supplies, namely, acquirement by purchase of the watershed, diversion of isolated and community sewage from the streams draining the watershed, community sewage purification where diversion is neither feasible nor possible, and intense watershed patrol. The author wishes to place himself on record emphatically as favoring any and all reasonable attempts to head off at the source dangerous pollution of surface waters. Unfortunately, however, there is a marked tendency in some localities to place too great reliance on this form of water-borne disease prevention. It is all right so far as it goes, but it is not the Q. E. D. of the problem of satisfactory public water supply by a long shot.

Under normal circumstances the acquirement by purchase of the entire catchment area is too expensive an undertaking to be considered for more than a brief moment. Furthermore, a catchment area being purchased in its entirety, the circumscribed landscape profusely dotted with "No Trespass" notices, and the often more or less somnolent patrol given the charge of enforcing the no-trespass rule, does not and cannot afford adequate assurance that the waters flowing from that area, uninhabited except by the patrol or chance trespassers, will not at some time become the vehicle of disease germs, grievously to upset the calculations of the fathers of the primary prevention idea, and the inner mechanisms of the innocent ultimate consumers of these waters if furnished to them without purification.

A large proportion of Americans are imbued with the idea that democracy, liberty, freedom and the rest of our high flung but more or less fanciful shibboleths spell license and authority to do as they

please. This idea, initiated by Eve who partook of the forbidden fruit under the urgency of his Gehennic majesty that she assert her independence, is developed to a far greater degree in the American that in any other nationality. The German obeys the ubiquitous "Verboten" of his country because he has been taught to respect his national laws; the Englishman follows the set lines of procedure in his country because the other thing "isn't done;" but the American will travel far to circumvent the law in order to show his independence of authority and his ingrained repugnance of organized efforts to curb his natural impulses. In this connection witness the lengths to which the average American will go, the chances he will take and the money he willingly squanders in order to beat the Volstead Act. Men who never took a drink in their lives before the passage of this law now are competent authorities on home brew.

Take a watershed and remove all habitations from it, place a sanitary patrol on the job to prevent the deposition of human excrementitious matter; and if there are birds or rabbits in the woods, or fish in the brooks thereon, or wild berries or flowers for the picking, that patrol must be a mighty energetic and conscience driven body, individually as well as collectively, to stop at the indefinite confines of the watershed the rabbit hunter, the fisherman, the berry picker and the nature-loving flower gatherer. Then, too, patrolling a watershed is a lonesome job akin to sheep herding, and a little pleasant time-consuming intercourse with potential trespassers is not always rejected by the stern dictates of duty.

The public *will* enter upon the sacred confines of a watershed whose soil is dedicated by its purchasers to an eternity of hoped for immaculateness. Such trespassers may be uninvited, and perhaps unwitting, violaters of these hallowed premises, but anybody who has ever viewed a "Battle Royal" knows how difficult it is for a participant to keep an eye on the other contestants every one of whom is imbued with an all-embracing desire to hand him the lethal punch. Similarly, while passing the time of day or administering a reproof to one trespasser two more at another point may enter upon the ground a patrolman is guarding.

Any one of these, even the patrolman himself, may be an unsuspecting carrier of disease germs. When Nature calls, and her message is of a certain character, we all obey that call without unnecessary delay. If we are supporting an incipient case of typhoid fever we respond with even greater celerity than when we are not.

The nearest cover is promptly sought, and the urge of Nature satisfied. Thereafter a little shower of rain, a short aqueous travel from the clump of bushes to the nearest stream, and Mr. and Mrs. Bacillus Typhosus and the children have carried the movement to a point where, without the inhibiting activities of sedimentation, filtration and sterilization, the consumer of the water from this patrolled and supposedly immaculate watershed, soon will have a "little movement with a meaning all its own."

What water storage will do. Where it is feasible on engineering and financial grounds to impound surface water supplies in natural ponds, lakes or artificial reservoirs, there is no question about the advisability of availing of this line of defense between the gathering ground and the ultimate consumer. The trouble is that too great and unwarranted confidence has been placed in water storage competently, uninterruptedly, and consistently to remove the menace from such disease germs as may find their way into storage reservoirs.

The value of storage in the correction of the physical and hygienic imperfections of surface waters is very largely measured by the period of that storage; that is, the time elapsing between the entrance and exit of the water in the reservoir. Factors which upset a definite measure of the benefits of water storage are stratification and various currents, temperature changes, and wind action. A reservoir may have a theoretical displacement period of 100 days, and be considered in consequence a pretty fair purifying medium; but short-circuiting of the flow through the reservoir may actually cut the theoretical period of storage to a very few days, or even hours, and by the same token this identical reservoir of which so much is theoretically to be expected may then prove to be a delusion and a snare. Particularly is this condition aggravated when most of the reservoir surface is frozen over and the discharges from the entering streams follow a quite direct line from their points of entrance to the outlet of the reservoir. Temperature changes in the spring and autumn of the year, bringing about the periodic "overturns" which produce complete vertical mixing of the waters of the reservoir, upset all theoretical calculations. Strong winds toward the reservoir outlet tend to carry swiftly thereto the entering waters of the streams which feed it.

Water storage, in the concrete, will reduce the physical imperfections of a water through sedimentation, in extent depending

directly upon the degree of quiescence, the period of storage, and the hydraulic subsiding values of the particles of suspended matter the water initially contains. It will reduce somewhat the color of water due to vegetable stain through the bleaching action of the sun, but the sun is off duty for more than half the time, and even when patrolling its beat its bleaching action is manifested only at or relatively near the surface. Finally, and what is by far the most important, storage of water will reduce the numbers of disease bacteria to a marked degree through the agencies of unfavorable environment, sedimentation, insufficient and unsuited bacterial food supply and the inimical activities of predatory protoza.

What water storage will not do. Storage of surface water in natural lakes and artificial reservoirs produces a beneficial effect upon its physical and hygienic qualities as an average proposition, but its action is not thorough, nor is it consistently reliable. If polluted water enters a reservoir the chances are a hundred to one that sometime, under the primary influence of freshets, short-circuited flows, seasonal overturns or what not, that pollution, in part at least, will find its way to the outlet of the reservoir. The pollution entering the reservoir need not be continuous or large in volume. Indeed, the evidence is striking on the point that the disease-germ infected excrement of only one or two persons is sufficient to contaminate with disastrous results surprisingly large volumes of water. The experiences at Plymouth, Pa., New Haven, Conn., York, Pa., and Scranton, Pa., furnish incontrovertible evidence on this point.

Regardless of all the legislative action in the world, and all the efforts on the part of patrolmen hired to prevent such things, people will fish and even bathe in waters impounded for public supply. There may be only a few who will display such indifference to the law but they exist nevertheless. Again, it has not been found impossible for favored ones with the necessary "pull" to obtain limited permits to fish in such waters. These people have only to be suffering from typhoid fever at the time to make almost inevitable the pollution by them of the waters in which they are fishing. One person can discharge in one evacuation of urine enough typhoid germs to place one or more of these germs in every glassful of a 5,000,000,000-gallon reservoir. Fishing or boating in impounded waters used for public supply without subsequent purification should never be permitted. Even the issuance of limited permits in special cases is a dangerous practice, for once out on the face of such waters

in a boat, and with the conveniences of the land a considerable distance away, the use of the water as a point of deposition of dejecta is almost inevitable, and there is no assurance that the person to whom a permit of this character is granted is not unknowingly suffering from incipient typhoid, or a typhoid carrier.[4]

In fine, while the storage of surface waters in large lakes or reservoirs has a decided beneficial effect on the quality of the water as an average proposition, it cannot be depended upon as a consistently reliable performer in the field of water purification. The benefits of storage are here today and gone tomorrow because of factors in themselves beyond the power of man to control. Where a community desires a water supply as safe as the natural conditions and the inventiveness of man can make it, and that water is derived from surface sources, something more is needed than the acquirement of the catchment area by purchase, its subsequent unremitting patrol, and the storage of the runoff for days, weeks, or months. Too many physical, thermal and human vagaries enter into the problem to make it permissible for the sanitarian to stop at this point. The procedure outlined may solve the conundrum for 364 days and 23 hours of the year, but in that one remaining hour all precedents, good intentions and convictions may be blasted from their inherently insecure foundations, and a disastrous epidemic of water-borne disease cast its pall of death upon a misguided community relying on part way means of prevention.

There is no sense at all in persistently residing in a fool's paradise. All surface waters, be they derived from perpetually snow-capped mountain regions or from acquired, untenanted and patrolled areas, are potentially dangerous in that they are open to incidental, accidental, or deliberate pollution. Storage of such waters cannot be relied upon to make them continuously safe for human consumption. To presume that storage can be so relied upon is to ignore the epidemics arising from polluted impounded water supplies, and which are a matter of undeniable record. Such a position is untenable; is unnecessary because of the existing knowledge of how to make public water supplies entirely and continuously

[4] A noteworthy addition to the literature on this phase of water storage was contributed last summer by X. H. Goodnough, director and chief engineer of the Department of Engineering, Massachusetts State Board of Health. It can be read with decided profit by those interested in the subject. See *Journal* New England Water Works Association, September, 1920, page 151.

safe by methods subsidiary to storage; is fanciful because those whose mentalities convince them that it can be done for the reason that no disaster has yet attended their own practice in that primary line of disease prevention alone, have not had their personal lesson; and romantic altogether in face of the facts. There is as much sense in such a position as there is in the report that "Mr. Jones fell from the second story of his home and broke his neck. Otherwise he was entirely uninjured."

Conclusions. The endeavor has been made to prove that the problem of making surface waters safe for public consumption involves the application of a chain of preventive measures constituting in effect four major lines of defense against water-borne disease, namely:

(*a*) Maintain the catchment area in as sanitary a condition as practicable; that is, guard against gross pollution entering the streams and lakes which drain the watershed.

(*b*) Store the water in natural lakes or artificial reservoirs, provided such storage is available or dictated by sound engineering principles.

(*c*) Coagulate and filter.

(*d*) Sterilize.

There will be some variations in the application of these measures. The first (*a*), stands always unchanged as an elemental requirement of common sense and decency.

In the case of the second (*b*), where natural facilities for storage are already at hand they will of course always be made use of. Where they are not, and the construction of a dam to form a reservoir is required, aside from the purely engineering aspects of this phase the only consideration which need be debated is whether or not the burden on the ultimate filter plant will be substantially lessened by pre-storage for a long period. If the raw water is grossly polluted or heavily charged with mud, silt or clay such storage is sometimes highly advantageous.

In the third case (*c*), there may be instances where coagulation is unnecessary and where cost and other factors, including local public sentiment, indicate slow sand filters. Only where coagulation is unnecessary, and where climatic conditions and the chemical composition of the raw water are favorable to such treatment, should slow sand filters be considered. The author prefers the rapid sand filter in any and all cases. It is less easily upset by climatic changes, and in competent hands is susceptible of less likeli-

hood of "going wrong," and of more ready readjustment if it should, than is the old-fashioned slow sand filter.

Respecting sterilization (*d*), this should never be omitted from the list of preventive measures. It is not a 100 per cent safeguard when used alone except in those very rare cases where the raw water is all of the time, without any exception, free from suspended matter. In all cases the practice should be maintained of applying the sterilizing agent continuously, never periodically. To sterilize only when it "seems to be necessary" is as pernicious a practice as temporarily suspending the operation of a filter plant or the use of a coagulant when the water looks all right.

In by far the great majority of relatively large communities the problem of protecting the public from water-borne disease should embrace the application of watershed pollution minimization, and purification by sedimentation, coagulation, filtration, and sterilization. Any community using surface water would do mighty well to set up for continuous maintenance all of these lines of defense. To rely solely on the primary line of prevention, watershed patrol and water storage, is to invite inevitable disaster. Disease germs never send a herald in advance to proclaim their coming, and it is true water works and general civic economy always to be thoroughly prepared for their complete and satisfactory reception. Then, but not otherwise, the ultimate water consumer may drink, not only with his eyes, but freely, satisfyingly, and without hazard of his life.

DISCUSSION

J. W. Ellms:[5] In this paper the author has pointed out the potential danger in depending alone upon the storage of public water supplies derived from surface sources for the elimination of pollution. He shows the weakness of the ordinary preventive measures employed, and the absolute need for the dependable processes of filtration and sterilization. With the author's point of view the writer is in entire accord.

Probably there is nothing more difficult to change than human opinions, and especially where such opinions are based upon custom and practice, and where there is possibly an unconscious prejudice against the remedies suggested for effecting a change. Although the opposition to modern methods of water purification, especially

[5] Frazier-Ellms-Sheal Co., Consulting Engineers, Cleveland.

where chemical coagulating and sterilizing agents are employed, is by no means as pronounced or as open as formerly, nevertheless it still lingers in the mind of the layman more often than is usually suspected; it is even latent in many sanitarians, who will resort consciously or unconsciously to such measures as storage of surface waters or methods of filtration known to be inadequate for the problem in hand. The impounding of surface waters has its place from a sanitary standpoint in every system of water supply where it can be used; but for reliance to be placed upon it as a sole or even principal measure of purification is futile and dangerous, and becomes more so as the population on watersheds increases.

Sanitary engineers have made remarkable inroads upon the devastation wrought by typhoid fever in the United States by cleaning up its water supplies. However, much remains to be done, and much may still be done by recognizing the inadequacy of so-called "natural methods of water purification," and by insisting upon utilizing and perfecting the well known and thoroughly proven methods of purification now available. Infant mortality and morbidity must still be reckoned with, even though the typhoid fever death rate may be low, for there is a well grounded suspicion amongst physicians that impure or poorly purified water supplies are frequently responsible for the sickness and early death of many children.

Engineers are much indebted to Colonel Johnson for his persistent efforts in showing the dangers of water-borne diseases, which he so well described in his previous paper on the "Typhoid Toll," and which he has most admirably supplemented by the paper under discussion.

Theodore Horton:[6] Whether the subject is viewed as romance or tragedy, the writer feels substantially in accord with the facts, views and conclusions of this paper. He also is quite in sympathy with the intolerance expressed by the author toward that group of altruists, or theorists or reactionists, whatever you may be pleased to call them, who find it difficult to distinguish between principles and practice, to readjust their views in the light of changing experience, and to realize what is meant by safety when applied to public health and human life.

Fortunately the work of State Departments of Health which have established engineering divisions whose activities extend to

[6] Chief Engineer, New York State Department of Health, Albany.

supervision of public water supplies, affords fruitful opportunities to observe, on ample numerical scale, the effects which various and changing conditions of arrangements and operations of water works have upon the public health of communities. These variations cover a wide range of conditions respecting character and intensities of pollution on the one hand and natural and artificial means of removing it on the other hand. Particularly is this so in regard to facilities for determining those factors as furnished by laboratory tests, sanitary survey and epidemiological data.

With some 550 public water supplies in New York State, all of which have been fully investigated, and many repeatedly reinvestigated, by the Engineering Division of the State Department of Health, with such facilities as a Vital Statistics Division always at hand to furnish statistics as to incidence of typhoid fever and other water-borne diseases, with a Laboratory Division always available to make analyses as occasion requires, and with experience of numerous outbreaks in the past, the history of which has furnished epidemiological evidence of sources of infection, it has been possible to repeatedly compare both absolute and relative efficacies of various natural and artificial conditions and safeguards of many of these water supplies. These investigations and studies have now been carried on for some fifteen years, during which most of these supplies have been greatly improved in sanitary quality, some through improvement on the watershed, others by storage, still others by filtration or chlorination or both. To be more explicit, in 1906 there were approximately 400 public water supplies in the state, serving a population of about 6,000,000 persons. Of these supplies about 50, serving a population of 700,000, received some sort of treatment, either by slow sand or mechanical filtration. In 1919 there were approximately 530 public water supplies in the state, serving a population of approximately 8,5000,000. Of these supplies, about 130, serving a population of approximately 6,900,000, are treated either by filtration or chlorination. This means that in the thirteen years, from 1906 to 1919, the number of persons supplied with public water supplies had increased from 6,100,000 to 8,500,000, or approximately 40 per cent; while in the same period the number of persons protected by water purification in some form, had increased from 700,000 to 6,900,000, or an increase of almost 1000 per cent. During this period also the typhoid rate for the state which, prior to 1906, had averaged about 23, has been reduced from about 20 in 1906 to 3.0 in 1920.

During these years of struggle for better water supplies, which has resulted in almost an elimination of typhoid fever from the state, many lessons were learned of the efficacy and the limitations of the many natural and artificial measures in the protection of public water supplies. Among these lessons, as bearing especially upon the subject of the paper may be mentioned, first, that what might be termed "natural protection," or the exclusion of pollution from the water supplies and the watershed, while desirable in any case, is in no case a sufficient or satisfactory safeguard to any supply. It must, of course, be admitted that within reasonable limits of cost, and for aesthetic considerations, such precautionary measures are always desirable. As an only safeguard, however, it is entirely inadequate; and experience in New York State has fully demonstrated that not only are such supplies, only so protected, always subject to the imminent danger of incidental, accidental and wilful contamination, with its always possible infection, but that it is only through artificial and other more effective means of protection, accomplished through some sort of purification, be it no more than chlorination, can those supplies be effectively protected. Furthermore the writer is convinced that on sparsely inhabited, or even so-called uninhabited watersheds, a greater degree of security can be afforded by chlorination, notwithstanding its limitations, than by methods of patrol, for the same expenditure of money. Thus, to be even more explicit, the writer feels that the old traditional notion of relying upon sanitary patrol of a watershed to maintain a supply pure, in place of artificial protection, should, in the light of present knowledge, be reversed; that is, it will be safer to first chlorinate (or filter if that can be afforded) and then clean up the watershed and maintain it as clean as practicable (at least from direct sources of contamination), always keeping in mind that the so-called "uninhabited watershed" does not exist as a reality in these days when the hunter, fisherman, tramper, canoeist, picnicker, to say nothing of sea gulls and other scavengers, all contribute their share of contamination and possible infection.

Another lesson which experience has clearly and repeatedly demonstrated in this State is the one brought out by the author that storage of water in reservoirs, lakes and ponds can only be depended upon as a very crude barrier of defense. The writer does not mean to underestimate the great value of storage when the full effect is felt. This effect however, only rarely occurs, and while

the author has referred to thermal changes, overturn and wind currents, he has perhaps not emphasized as much as he might, the importance of this latter influence. The atmosphere is nearly always in motion, and few are the days during any year when this action, based upon the well established ratios of wind velocities to induced currents, will not produce currents sufficient to carry pollution a distance of 4 or 5 miles; and on many days 50 miles.

Many factors, of course, contribute to lessen the effect of contamination carried by surface currents in this fashion, such as sedimentation, dilution and sunlight, as mentioned by the author, and this may account for the traditional notions still held by some as to the great value of storage. When one considers, however, that there are comparatively few days in the year when the wind action will not carry surface pollution from nearby, and even distant shores, to water intakes; that these surface currents are likely to keep bacteria in a state of suspension; that these time intervals of travel are too short for sunlight to be very effective, there seems to be little left in the "storage theory," in the language of the author, but romance. In fact, New York State has furnished a number of epidemics due to infection conveyed by wind currents in lakes, and one of these during the present year. Furthermore, if one will study the analytical results of water supplies taken from lakes and reservoirs, even though subject to only slight pollution and with intakes favorable located, he will generally find that at intervals, usually irregular but occasionally seasonal, and depending upon position of polluting source and prevailing direction of winds, B. coli and other evidence of contamination will appear and that at other times the water may show no contamination whatever.

If safety means anything, it means safety at all times. It means protection not only from direct sources of pollution on an inhabited watershed, but from the hunter, fisherman, bather and others who may stray onto or even camp upon our so-called "uninhabited watershed." This protection may be fairly well afforded by such barriers as watershed patrol, warning signs, water storage, and properly located intakes; but if a supply is to be made safe against not only direct sources of pollution but also incidental, accidental, and wilful contamination derived from possible typhoid carriers roaming promiscuously over the watershed, or from the ofttimes referred to "harmless surface drainage from farm lands," any coli from which will be attributed to the cattle and not the human

beings who care for them, it will be necessary to resort to the more definite, positive and reliable means of protection which the now highly developed art of water purification has placed at our disposal.

H. W. CLARK:[7] It is a pleasure to comply with a request to discuss this paper, especially in view of Colonel Johnson's discussion of the writer's paper before the New England Water Works Association last September and the fact that the present paper appears to be a continuation of that discussion.

There is no doubt in the writer's mind that Colonel Johnson states a self-evident proposition, known to every water works engineer and expert, when he calls attention to the fact that depopulation and sanitary control of watersheds, storage of water in reservoirs, filtration and sterilization are all of great value in rendering surface water supplies safe to their consumers. He probably has no greater faith in filtration than the writer, who has had investigations on that subject under his direction for more than a quarter of a century, has directed and improved at various times the operation of a number of municipal filters, both slow sand and mechanical, in New England and elsewhere, and can with all due modesty say that he has planned and overseen the construction of a municipal filter or two here and there in this country. The various historic epidemics of typhoid caused by water, referred to by Colonel Johnson and quoted by Mr. Goodnough in his paper before the New England Water Works Association Convention in September, 1920, are also well-known to the writer. He would only call attention again to the facts, as he did on a former occasion, that in Massachusetts dependence on storage of surface water for safety is still largely relied upon, that comparatively few filters are in operation here and that, notwithstanding the State's culpability in this respect, according to Colonel Johnson, Massachusetts is believed to have the lowest typhoid death rate of any state in the country and no waterborne epidemic of this disease has disturbed it for many years. This does not mean that the State may not have such an epidemic or that the writer does not believe in filtration, but the probability of such epidemics from stored water unfiltered becomes less and less as typhoid dies out here, as it apparently is doing, and the number of cases of wandering typhoid patients diminishes as it undoubtedly has during the past few years.

[7] Chief Chemist, Department of Public Health of Massachusetts, Boston.

Colonel Johnson is apparently disturbed because a more active propaganda is not carried on here to urge or force the installation of filters and apparently wonders that the State Department of Health is able to sleep o'nights with so much unfiltered surface water coming into Massachusetts homes day after day. As a matter of fact, the Department has little or no mandatory power in this matter of filtration and it can hardly, considering the remarkable local freedom from typhoid, hang out the red flag of warning too conspicuously or in too large pattern because there was a typhoid epidemic due to polluted water in Plymouth, Pa., in 1885, or one in New Haven, Conn., in 1901. This is not said flippantly. Reason and common sense in health matters are as necessary as in other mortal affairs and the State has a large body of intelligent and capable water works officials, most of whom are conversant with the relation of water supplies to health.

The writer would conclude by saying again, as he has often said in the past, that personally he prefers a surface water filtered for cleanliness as well as for safety, and believes that cleanliness should be dwelt upon more than it generally is by water works engineers, but nevertheless the facts in regard to storage, filtration and typhoid in Massachusetts are as stated in his paper before the New England Water Works Association Convention in September, 1920, and as he has briefly summarized them here.

E. E. Lochridge:[8] Colonel Johnson has outlined the case for the careful purification of water very fully. As time goes on the users of city water are becoming more exacting in their demands. They insist that the water should have not only the purity which was somewhat rare a few years ago, but also pleasing appearance and taste. It is safe to say that no municipality which has ever been furnished a nice appearing water in which there was the utmost confidence of its purity, is ever willing to accept a water that is in any way less desirable.

While wonderful results have been obtained by storage, by careful control of watersheds, and by other means which tend to make a natural water safe, there is, nevertheless, a constantly growing demand for a purification which would make the quality of the water uniform at all times.

[8] Engineer, Water Department, Springfield, Mass.

In his conclusions Colonel Johnson advises the maintenance of the catchment area in as sanitary a condition as practical as a minor requirement; depending upon the storage, coagulation, filtration, and sterilization to complete the work. The only exception which could be taken to this, it would seem, would be that in cases where it is practicable, the prevention of pollution should be as systematic as possible, in order that there may be every possible guarantee of a pure water from the start. This, of course, is not always possible; and, as the author points out, the chance pollution is a certainty at some time or other, to avoid which later processes should be maintained.

There will probably be a general acceptance of the conclusions drawn; not only from the standpoint of sanitation, but also for the general quality and appearance of the water.

W. H. Dittoe:[9] Colonel Johnson has quite frankly bared the facts concerning water supply protection and purification, and all who are unprejudiced must be convinced of the truth of his statements.

As its name implies, "water purification" is the process by means of which impure water is rendered pure. The process is not fully successful unless the final product is absolutely and continuously pure. No process of purification can be fully successful, therefore, if it is called upon to perform more work than it can reasonably be expected to accomplish from day to day and under all conditions. We must recognize the limitations of the various agencies of water purification and must employ these agencies with generous safety factors in order to insure a continuously pure product.

Protection and maintenance of watersheds, storage of water, coagulation and filtration, and disinfection have their respective limitations in converting impure water to pure water and these limitations must not be overlooked. There is a real need for a set of working standards to define the permissible and reasonable burdens which should be placed upon water purification processes. Likewise, uniform standards of quality of the product of the principal features of the process should be established. For instance, in the case of a rapid sand filter plant, standards of quality (bacteriological and physical) should be established as follows: First, of the water

[9] Chief Engineer, State Department of Health of Ohio, Columbus.

passing from the coagulation basins to these filters; second, of the water leaving the filters; and, third, of the filtered water after disinfection treatment. If the quality of the water applied to the filters is below the standard, obviously the succeeding processes will be called upon to perform more work than their reasonable share. This should be prevented by making such improvements or extensions in the processes preceding the filters as are necessary. In many instances it may be apparent that storage and plain sedimentation preceding coagulation will be necessary to produce the desired results.

In Ohio it is considered that the minimum necessary treatment of a water supply of surface origin demands coagulation, filtration and disinfection. It is not considered safe to depend upon storage, with watershed protection, even if the water is continuously treated for disinfection prior to delivery. In several instances in Ohio it has been attempted to provide satisfactory drinking water by the use of impounding and storage reservoirs in the development of surface water supplies, such reservoirs having holding capacities equivalent to one hundred days consumption or more. The results have been generally unsatisfactory and such water supplies have been objectionable at times, due to bacterial contamination and undesirable physical characteristics, the correction of which has demanded proper treatment by coagulation and filtration with disinfection as a final factor of safety. It should be stated that the topographical and geological conditions of Ohio and the nature of the industrial and agricultural development of the state generally do not favor the use of reservoirs except for purposes of securing an adequate water supply and providing the primary step in purification.

In no instance in Ohio has a municipality or water company attempted to control its water supply by purchasing the entire catchment area and the State Department of Health, recognizing the great expenditures required and the uncertainty of securing safety in this manner, has not encouraged such purchases. Reasonable protection and maintenance of watersheds can be secured without purchase under Ohio Laws and the saving of funds thus resulting is generally sufficient to pay the cost of constructing purification works.

The value of storage is recognized and in many instances it is employed as a preliminary step in purification, being followed by

processes of coagulation, filtration and disinfection. Storage is advantageous in this connection, not only as a step in purification but also as a means of equalizing the chemical and physical quality of the water for treatment. This equalization simplifies plant operation and results in more regular efficiencies.

Richard Messer:[10] Colonel Johnson has set before the Association an ideal with regard to the standard for drinking water, which it is hoped will soon be accepted by the public generally. The wonderful accomplishments in the field of water purification during the short period of thirty years, which have resulted in such a remarkable reduction in rates of typhoid and other diseases recognized as being due to impure drinking water, seems almost unbelievable. What improvements and changes in methods will occur during the next thirty years nobody can predict, although one thing is certain, that the time is fast approaching when there will be few, if any, cases of typhoid or other intestinal diseases due to drinking water furnished for municipal use.

The writer is in full agreement with the stand taken by the author that there are few, if any, exceptions to the general rule that surface waters, no matter under what conditions they are collected, are potentially dangerous, and therefore should be artificially treated by the most up-to-date methods, before the water is turned into the distribution system. It is all very well to talk about patrolling a watershed, but in actual practice it is very difficult to prevent the pollution of the reservoir or tributary streams in some of the ways which have been mentioned in this paper. The writer has in mind two impounded supplies, the entire watersheds of which are owned by the cities and are under patrol. In these instances the most serious danger is from poachers who visit the reservoir at night or in the early hours of the morning. Consider for a moment a large reservoir originally stocked with game fish, in which fishing has been prohibited for a number of years. To a person who loves the sport, the temptation to take a chance, even though it means breaking rules and regulations and possible arrest, is often too great to resist. True, the number of watchmen might be increased but this means added expense, which in the opinion of the writer could to better advantage be put into the operation of a purification plant.

[10] Chief Engineer, Virginia State Board of Health, Richmond.

From time to time pathetic letters are received, petitioning the State Board of Health to lift the lid or grant special permits under certain rigid conditions. The writer recalls one argument presented to the effect that the city water had a "fishy odor," that this was due to the excessive number of fish in the reservoir, and calling upon the Board to permit the members of a certain club to assist the city in removing them. Needless to say copper sulphate was applied instead.

During the past years the government, through its Forest Service, has acquired large tracts of land to be held as reservations. When possible, the Service has selected areas from which public supplies are collected and in this way has helped materially in preventing pollution. However, if the reservations are to serve the purpose for which they are acquired, the trees will have to be cut and removed some day, with the possibility of dangerous contamination of the supply. Nevertheless the policy of the Forest Service in giving preference when possible to public water supply catchment areas, is to be encouraged. At the present time several of the smaller towns in Virginia collect their supplies from areas which are entirely owned by the government.

In the State of Virginia there are nine impounded supplies, serving cities of 10,000 and over. Of these, six are filtered and chlorinated and catchment areas of the other four are entirely owned by he municipality or private companies. It should be mentioned, however, that the filter plants were installed for other than sanitary reasons, those in eastern Virginia because the impounded waters are highly colored and are subject to algae troubles and those in the central and western part of the state because the waters are usually turbid, due to the red clay soil, and also subject to algae troubles. One of the cities has spent about $300,000 to filter a water taken from a catchment area of 39 square miles, almost half of which is owned by the city. The original plan was to purchase the entire area but afterwards it was decided that this was too expensive an undertaking and that filtration would be the wisest course. The other four places referred to will in all probability decide to resort to aeration and filtration before many years in order to secure a supply which is entirely satisfactory.

It is very interesting to note the change in sentiment on the part of the public during the past ten years in demanding water not only safe but with the best possible physical quality. We no longer have to

explain the advantages of such a supply because the thinking people take these things for granted. The only questions at issue are with regard to the financing of the work and the extra cost of operation.

One of the most difficult problems in connection with the state supervision of public supplies is the control of the medium size and small filtration plants. With the highly turbid water and with the aid of chlorine, fairly satisfactory results are obtained. Nevertheless, a small filter plant, no matter how carefully designed, will go wrong at times, due to carelessness and ignorance on the part of the attendant. For obvious reasons a town of 5000 or 6000 population, or smaller, cannot afford to employ a skilled operator, or at least the officials cannot see their way clear to do so. Although the writer is fully aware that any apparatus like a filter plant, requires fairly intelligent care and operation to function satisfactorily, nevertheless he ventures the suggestion that additional safeguards must be considered by the designer of these smaller plants, which will never receive the expert attention required for larger installations. How can the factor of safety be increased by the designer? Will longer periods of coagulation, finer sand and slower rates help in this? The writer believes that the peculiar requirements for a smaller installation must be given farther study with the view of making such a plant as nearly "fool proof" as possible, especially in view of the rapidly increasing number of these smaller plants which are being constructed each year as compared with the few larger installations. Most of the larger cities are already cared for and the smaller places are demanding equally good water.

JOHN M. DIVEN:[11] One of the unexpected sources of possible pollution of a stored water occurred in the writer's experience. The reservoir was a large one as compared with the amount of water drawn, and the movement of the water very slow. The outlet gate house was so located as to be a long distance from any inlet stream of appreciable volume. The water movement was thoroughly tested by means of floats so constructed as to catch the effect of any currents at varying depths. The ice movement was studied by means of beer kegs (if you know what is meant) painted in various colors and numbered, distributed at many points on the ice and closely watched when the ice broke up in the spring.

[11] Secretary, American Water Works Association, New York.

The movement of both water and ice towards the gate house was so slow that it seemed unlikely that it would flow or float from any probable source of pollution to the gate house within the life of any pathogenic bacteria. The water was considered a 'safe' and satisfactory supply and bacteriological analyses had always carried out this supposition. The typhoid rate in the city was very low.

Some trouble with a concrete spillway made it necessary to draw the water down about 5 feet during a cold winter. The ice, where cut back of the spillway, measured 26 inches in thickness. At the rather shallow outlet or mouth of one of the principal streams feeding the reservoir, the ice settled on the bottom the entire width of the stream and for a considerable length In the spring weather when the stream "broke up," the flow did not break up or lift the ice at their mouths, but the water ran over the heavy reservoir ice, which had not broken up. This spring flood water was naturally turbid, and from the stream entering the reservoir nearest to the gate house, a distance of about 1½ miles, the muddy water flowed over the ice directly to the gate house. Turbid water soon appeared in the city mains, something hitherto unknown from this source of supply. Immediately samples were taken for analysis, and a hurried visit to the reservoir revealed the cause. For though the warm water and increased flow had broken the ice at the mouth of the creek, and conditions were very quickly back to normal, the course of the muddy water over the ice could be clearly seen, a muddy fan-shaped streak. The water had made the journey, usually taking months, in a few minutes.

Fortunately there were very few sources of pollution on the stream, and the bacteriological examination showed coli absent. However, this might have been different, and, needless to say, dynamite was used at the mouth of the stream the next winter. The "phenomenon" of water putting on skates and racing to the gate house did not occur at the mouths of the other confluent streams owing to a different conformation of stream beds and banks. The incident, however, shows an added reason for not depending entirely on sedimentation for safety in a water supply.

C. A. Emerson:[12] Each impounded supply that is rendered safe by some positive treatment not only protects the consumers of the district against water-borne disease, but serves as a missionary

[12] Chief Engineer, Pennsylvania State Department of Health, Harrisburg.

to the "conservative" owners or consumers of water supplies in neighboring municipalities which are not so protected.

Even in spite of all that has been said regarding the danger of using untreated surface supplies, how frequently in the case of the small waterworks taking a supply from a reservoir in a forest reserve or in waste mountain lands with but a few habitations and slightly travelled highways on the watershed, do we find every consumer is only too willing to swear "that we have the finest water in the world." Chlorination is mentioned as a necessary safeguard and factor of safety and to a man they "don't want dope put in that water," particularly as some public spirited citizen has spread the gospel that chlorine is the "same stuff the German used to poison our boys during the war."

Oftentimes, this reaction against chlorination is well founded and is based upon a vivid recollection of the taste in the water of some neighboring community. Too frequently, the proponents of this treatment feel their duty is well accomplished when the apparatus has been installed and payment received. They go their way with a sense of having benefited humanity and then in a deplorably large percentage of cases the local waterworks officials promptly overdose the supply. As soon as complaints begin to pour in the germicide is reduced to such an extent that its value is negligible. If every member of this Association having to do with a waterworks making use of chlorination would determine that in his particular plant the rate of application would be gauged by one of the simple tests for residual chlorine, made at least twice each day and the results checked by frequent bacteriologic examinations, much of the prejudice against this valuable method of treatment would disappear.

The adherents of longtime storage frequently make a grievous error, pointed out but not particulatly emphasized by the author, namely, failure to consider the variation from the nominal detention period in the reservoir which occurs during seasons of high stream flow, when the volume of water wasting over the spillway continuously for days or weeks, is many times the water consumption and also during a protracted drought when the reservoirs are nearly empty. In these cases the nominal detention may be reduced from a period of several months to only a few days, so short in fact, that even neglecting wind action or short circuiting due to other causes, the improvement in quality of the water gained by storage practically disappears.

The extension of improved highways and the phenomenal increase in number of motor vehicles have a material influence on impounded water supplies. A few years ago when Sunday and holiday picnics were limited to a horse and buggy trip of a few miles or a trolley ride to a well improved resort, many watersheds were rarely visited by the public, but now-a-days these same watersheds may be traversed by scores of people who are totally unaware that the small stream flowing through the attractive woodland reached by only a "short run" from the main highway is the water supply for a city and consequently take no thought to guard against pollution of the banks.

In Pennsylvania the value of chlorination as a further safeguard to the purity of impounded water supplies is fully realized as witnessed by over eighty-five installations on such supplies, but at the same time it is believed attention should continually be called to the shortcoming of chlorination, as for instance, when duplicate apparatus is not available, when the water is occasionally turbid or when the installations are so remotely situated that the apparatus receives only slight attention. The low cost of chlorine treatment appeals to all, but it must not be offered as a substitute for filtration unless a careful study by competent judges demonstrates that filtration is not required.

C. Arthur Brown:[13] If a rigid interpretation is placed on some of the statements in Colonel Johnson's paper, the writer is only partially in harmony with his views. To attempt complete and adequate control of catchment areas, in the vast majority of cases, is obviously impractical. Even in cities where the catchment area is small enough to permit some sort of control, the expense is usually too great to make it attractive.

Regardless of expense, the efficiency of such control is dependent on the human equation. To depend on this is to take chances, and to violate the good old maxim: "It is better to be safe than sorry." To reduce the human equation to the minimum is merely sound engineering. Therefore, the writer is in accord with Colonel Johnson in believing it to be poor engineering to rely solely on the ownership or control of the watershed, regardless of expense or care taken to protect the supply.

To admit this, and most of the advocates of control will admit it, necessitates impounding reservoirs as an additional precaution.

[13] Sanitary Engineer, Lorain, Ohio.

If the reservoirs cannot be depended on to overcome entirely what the care of the catchment area fails to do, then the combined control of watershed and the use of impounding reservoirs must be deemed inadequate. Experience had shown the folly of attempting to obtain a pure supply by care of the catchment area without using impounding reservoirs. It has also shown the folly of relying on the impounding reservoirs alone. To make the combined use of the two ineffective, it is required only that the time periods of failure in each be made coincident. The writer is certainly in accord with Colonel Johnson in thinking it unwise to rely upon this lack of coincidence. If the supply is bad enough to require control of the catchment area and the use of impounding reservoirs, it is certainly bad enough to require filtration.

To go to great expense in attempting to own and control the catchment area and to build expensive impounding reservoirs is not, to our way of thinking, good engineering practice. It savors of putting the cart ahead of the horse. A properly designed filtration plant of adequate capacity will usually be found cheaper in the majority of cases. It is a more flexible and consistently reliable means of obtaining a pure water than either or both of the previous mentioned methods. It will usually be found cheaper to operate. It would be better first, to provide the filter plant, then, if necessary, to effect control of the catchment area and build such reservoirs as are found necessary.

Up to this point, the writer is in agreement with Colonel Johnson, but when he states that all supplies should be chlorinated all the time, the writer begs leave to differ. He does not believe that chlorine should be used all the time to chlorinate all filtered water, nor does he believe that any filtered water should be chlorinated all the time. On the contrary, he is of the opinion that no filtered water should ever be chlorinated except as an emergency measure or under such restrictions as to leave the treated water absolutely free from objectionable odors or tastes.

The use of chlorine in treatment of filtered water has done more to retard progress and destroy the morale of operators than any other single cause. It is now responsible for holding up more permanent betterments of public water supplies than all other causes put together.

It is bad enough to overdose a natural water with chlorine to a point where it is more than reminiscent of a dissecting room, but

to treat a filtered water with this nauseating gas to a point where the odor and taste of the filtered water is such as to render it so objectionable that the average user cannot drink it without gagging over each glassful, and where even tea and coffee made from the water smell so vilely and taste so disgustingly that even a white mule offers an acceptable contrast, may be deemed good practice by some overzealous sanitarians, but as far as the writer is concerned he personally would prefer a water of great palatability and less freedom from bacteria of doubtful pathogencity.

The use of this gas in such excess to produce these sickening odors and tastes may be necessary to render an unfiltered water sanitary. But if the efficiency of the process requires its use to the point of rendering a filtered supply as malodorous as many of those within the writer's knowledge, it is high time that we evolve a better practice.

A properly designed and operated mechanical filter does not require chlorine to produce results. If chlorine is required it is proof the filters are not being operated as they should and the obvious remedy is to bring the filters to the required degree of efficiency. The proponents of this method of rendering a water unfit for human consumption may argue that the average plant and operator of today are unable to produce such results. If this condition obtains it must be charged largely to the use of chlorine.

In dozens of plants operators have been heard to say there was no use in keeping the filters up to their maximum efficiency. They argue that when the filters fail to produce satisfactory results, it is unnecessary to bother about the filters. All that is required is to increase the amount of chlorine to be applied.

The public, justifiably, is very sensitive about the odor and taste of its drinking water. Most of the opposition to water purification systems of today is based on this objection of the public to vile odors and tastes in the purified water. If the taste and smell of a filtered water is so objectionable as to render it unsuited for human consumption, it is no more fit to be used than it would be if it were sweet and palatable and contained a few bacteria of doubtful origin. In fact, we should prefer the latter water.

In order to avoid the occasional use of water overtreated with chlorine to the point where it becomes seriously objectionable, some objectors have gone so far as to install equipment in their homes to render the water sweet and palatable. The expense of such equipment varies from $250 to $500 per family.

With these known facts staring us in the face, the writer feels justified in voicing a disagreement with Colonel Johnson in his statements about chlorination. Furthermore, he believes that we are standing in our own light when we, as engineers, permit such conditions to continue.

There are dozens of cities in the country where bond issues have failed because of the objection of the public to the odors and tastes of filtered supplies. Personally, the writer has a lot of sympathy with any objector who refuses to vote money to build plants to use chlorine to overtreat a water. If the filtered water is to taste and smell no better than the natural water, why build a filter plant?

The sooner the engineer sees he is destroying his own business by permitting this condition to continue, the better it will be for the engineer. The sooner the public learns that it is unnecessary to use chlorine to this point in a properly designed and operated filter plant, the sooner we may look for a better support by the public of the construction of such plants and the less opposition we will encounter to the permanent improvement and betterment of public water supply.

The interest of the public should be the interest of the engineer. If we, as engineers, do not conserve this interest, we are illogical in expecting the support of the public, and the writer contends that we, as engineers, should correct this erroneous belief and restrict the use of chlorine to the point where it will never be possible to produce an objectionable odor or taste in a filtered water.

In order to do this it is essential that the filters be maintained in the condition to produce water of the required degree of purity without resorting to the use of liquid chlorine. This is entirely feasible. If the plant be well designed and well operated, it can produce water of the required degree of purity. If it does not produce water of the required degree of purity, then the operator should be required to take such steps as will bring the plant up to the required degree of efficiency. There are relatively few plants where the rate of 125,000,000 gallons per acre is not exceeded consistently where this may not be done, and in plants where it can not be done the faults are fairly obvious to an experienced engineer, and the means for correcting such faults are well known and should be used.

Our sanitary authorities, State Boards of Health, consulting engineers and filter builders can bring about this change, if they unite in doing so. The writer is quite aware of the fact that his views will

meet strong opposition. He has hesitated for sometime in giving voice to them, but he is satisfied that there are many evils to be charged to the use of this noxious gas which can be corrected, and which we, as engineers, should take definite and positive steps to correct.

Robert B. Morse:[11] It seems strange that it is still necessary to argue, before a technical body, points concerning which the evidence appears incontrovertible; to discuss the question that, because a thing has not occurred, it will not occur; to show that a chain is no stronger than its weakest link; to dally with the fact that the best of watershed control may not prevent pollution of a supply; to prove that the effective storage period in a reservoir cannot be measured by so simple an expression as the ratio of its full available capacity to the normal withdrawal from the reservoir; in short, to carry conviction everywhere that the best known methods of safeguarding our public water supplies should be employed without stint.

Apparently the necessity of discussing these matters before such an association as this, in the able manner that Colonel Johnson has, will continue at least as long as there is danger that engineers and sanitarians may be led not to adopt methods of water purification of comparatively recent development because, on the basis of past events, they may not seem to have been necessary in one section of the country.

Let our water supplies be "innocent." Lest, however, "repentance" overtake us, let them be innocent at the point of delivery as well as at the source; and if they cannot be kept innocent at both ends, let them assuredly be made innocent at the consumer's door.

There can be no quarrel with the school of sanitarians who "still cling to the idea that it is permissible to rely upon primary lines of defense against water-borne disease" and "offer vague arguments against water filtration and sterilization 'except where necessary.'" The case is stated exactly. Nobody would favor filtration and sterilization, or either one, except where necessary. But is the first of these methods of purification necessary only for making the physical quality of a water acceptable, or are one or both of them required as a sanitary measure only where waters are derived from

[11] Chief Engineer, Maryland State Department of Health, Baltimore; Chief Engineer, Washington Suburban Sanitary District, Washington.

inevitably polluted sources or are delivered without storage? In the writer's judgment, "where necessary" means in the great majority of places where supplies are taken from surface sources, even in sparsely settled regions, with the best regulated watershed control, even with long normal storage, and this in spite of a history of persistently low morbidity and in spite of any continued good analytical showing.

Maryland is not nearly as densely populated, on the average, as are some sections of the country; it cannot point to a long period of low prevalence of typhoid fever as supporting any policy of water treatment; but it is largely through strict adherence to the policy of purifying its surface water supplies that, within seven short years, the typhoid mortality in the whole state outside of Baltimore City has dropped from the forties to less than 9 per 100,000, and in this figure the strictly rural sections contribute mainly. Previous to 1914, with practically no state control over water supplies, no consistent progress had been made. In Baltimore, before the water was purified, the typhoid mortality rate was approximately the same as in the rest of the state, but now, after about a dozen years, it is four and a fraction.

The writer does believe it to be well worth while that over 97 per cent of Maryland's population, outside of Baltimore, served by surface water supplies, is using water that is either filtered, chlorinated, or filtered and chlorinated. If Baltimore is included, this figure rises to over 99 per cent. There are now only four small surface water supplies in the whole state that are not purified by one of these methods; in 1914 there were only five that were so purified.

The writer is not at all unmindful of the value of watershed patrol, watershed regulations and storage, as sanitary measures. He feels sure, however, that not many would advocate artificial storage reservoirs solely as a sanitary precaution, when surer and generally more economical measures are available.

Apparently, too little attention has been paid to the fact that storage is a relative term. Given an impounding reservoir, as generally constructed, the storage period may vary from time to time with atmospheric and other conditions. With varying winds and temperatures, short-circuiting currents, with flood run-offs perhaps a hundred or more times the volume of average inflow, with water level drawn down, with direct run-offs from ground surfaces near the reservoir outlet, how can it be figured that all the water at all

times receives the beneficent effect of long storage? How can one feel safe with so-called storage alone? When a storage reservoir can be constructed away from the stream from which it receives its supply, so that high run-offs cannot enter it, when it is of such shape and so arranged that its full displacement performs its function, when it is so protected that no direct surface wash can reach it, when it is of such size that all pathogenes in the entering water will die off before reaching the outlet, then, and then only, may one be assured of absolute safety in storage alone.

The sanitary value of storage in two Maryland reservoirs has been studied for the State Department of Health by two of the writer's assistants, Messrs. Wolman and Powell, for the purpose, in these cases, of investigating the results of subsequent purification by chlorination. One of these reservoirs was away from the stream from which it was supplied. It was found to comply essentially with the requirements of adequate storage except that it was not of sufficient capacity for its output. The other was an impounding reservoir formed by a dam built across the valley of the supplying stream, and subject therefore to high water conditions and direct surface wash. It was found, here, from a study of some eight months' duration, that the bacterial load on the liquid chlorine plant treating the effluent was extremely sensitive to lowered water levels, heavy rainfalls and rapid melting of heavy snow.

Reservoirs, either with short or long storage periods, by reason of their levelling influence, are valuable adjuncts to ease and economy of operation of subsequent purification works, but the writer believes it to be only rarely that they can be of such size, so arranged, and so guarded, as to compete economically, as a sanitary measure alone, with other methods of water purification. That confidence in the safety of rules and regulations for watershed control, and in ordinary storage, is misplaced, has been proven in the home of storage. It seems that the lesson that should have been learned from the sharp outbreak of intestinal disease at Peabody, Massachusetts, in 1913, was not learned at all, for we are told that the recommendation of the State Board of Health was that fishing in the reservoirs be prohibited and that the regulations established for the protection of the water supply be strictly enforced, not that the additional safeguard of further purification be applied to the stored water.

ESTABLISHING RATES FOR SERVICE RENDERED BY PUBLIC UTILITIES BY CONTRACT[1]

By Walter A. Shaw[2]

By an act of the Illinois Legislature, approved June 30, 1913, and in force January 1, 1914, there was established a rule by which it can be determined whether or not "all rates or other charges made, demanded or received by any public utility, or by any two or more public utilities, for any product or commodity furnished or to be furnished or for any service rendered or to be rendered" are just and reasonable.

Section 32 of the Act provides as follows:

> Every unjust or unreasonable charge made, demanded or received for such product or commodity or service is hereby prohibited and declared unlawful.

Section 41 of the Act also provides as follows:

> Whenever the Commission, after a hearing had upon its own motion or upon complaint, shall find that the rates or other charges, or classifications, or any of them, demanded, observed, charged or collected by any public utility for any service or product or commodity, or in connection therewith, including the rates or fares for excursion or commutation tickets, or that the rules, regulations, contracts, or practices, or any of them, affecting such rates or other charges, or classifications, or any of them, are unjust, unreasonable, discriminatory or preferential, or in any wise in violation of any provision of law, or that such rates or other charges or classifications are *insufficient*, the Commission shall determine the just, reasonable or sufficient rates or other charges, classifications, rules, regulations, contracts or practices to be thereafter observed and in force, and shall fix the same by order as hereinafter provided.

Attention is called to the fact that if the Commission after a hearing had upon its own motion or upon complaint, shall find the rates or other charges insufficient, the Commission shall determine the just,

[1] Read before the Illinois Section, March 23, 1921. Discussions are requested and should be sent to the Editor. See, also, discussion of next paper.

[2] Formerly member of the Public Utility Commission of Illinois; 30 North LaSalle St., Chicago, Ill.

reasonable or sufficient rates. From such action there is no escape unless the several individual Commissioners making up the Commission violate their oath of office.

In case Maclay Hoyne, State's Attorney, vs. The Chicago & Oak Park Elevated Railroad Company, in which an order of the Public Utilities Commission of Illnois was challenged in the raising of fares from five cents to six, Judge Baldwin of the Circuit Court of Cook County, in an opinion rendered January 22, 1919, said:

> They are, however, by the Public Utilities Act, charged with the duty (among others) of ascertaining whether the rates or charges of the Utilities Company are "insufficient, and, of course, that means insufficient as a reasonable and just rate."

As to what constitutes a just, reasonable or sufficient rate, the Supreme Court of Illinois in case, The State Public Utilities Commission ex. rel. The City of Springfield vs. The Springfield Gas and Electric Company (291 Ill., 219) said:

> The basis of all calculations as to the reasonableness of rates to be charged by a corporation maintaining a public utility under legislative sanction must be the fair value of the property being used by it for the convenience of the public, and in order to ascertain that value the original cost of construction, the amount expended in permanent improvements, the present cost of construction, the probable earning capacity of the property under the particular rates prescribed by statute, and the sum required to meet operating expenses, are all matters for consideration and are to be given such weight as may be just and right in each case.

The rule laid down by the Illinois Supreme Court to determine the reasonableness of rates to be charged by a public utility, is in full accord with the rule laid down by the United States Court and the Supreme Courts of other states.

In the Springfield Gas Case, *supra*, the Illinois Supreme Court at page 237, in concluding, said:

> After all, the questions presented in this case are largely questions of business judgment, and no rule can be laid down which can be applied mathematically to every situation. Each case must rest largely upon its own facts. We are aware of the grave character of the questions with which we have had to deal and of the great injury, not only to private interests but to the public at large, that may result from error. The same may be said of any legislative policy in matters of moment. We have dealt with the legal principles underlying this case, but the ultimate question is a question of business and results cannot be predicted. In such a case the Commissioners ought to move with

caution. An unwise administration of regulatory laws will drive capital from the field and bring on public calamity by causing the utilities to cease to function. It is equally important to the public and the utilities that the rates established be just and reasonable.

The above statement of the Supreme Court is so clear and convincing that no further comment is necessary.

During the latter one-half of 1920 and prior to the nomination and election of Governor of Illinois there was carried on against the outgoing State Administration a most vicious and vilifying campaign especially as to the work of the outgoing Public Utilities Commission. The favorite charge against the Commission and the one that met with apparent popular favor was that it disregarded all contract ordinances and contracts for rates contained therein, and farther charging that the Commission gave no more consideration to said alleged contracts than if they were mere scraps of paper, the same as "Kaiser Bill."

To more fully illustrate the charge against the old Commission thereby violating the constitution of the State and the laws of the land, the following quotation is made from a copy of resolutions adopted by the City Council of Quincy, Illinois, as read by Honorable Harry P. Pearsons, Mayor of the City of Evanston, Illinois, and for the past two years president of the Illinois Municipal League which is as follows:

The City Council of the City of Quincy, unanimously ask on behalf of the people of all parties of said city how you stand on the question of Public Utilities with relation to municipal home rule or local self-government.

This Council has repeatedly and unanimously declared itself in favor of municipal self-government in the matter of granting rights and privileges belonging to the people of a municipaltity and against the arbitrary annulment of the municipal rights in franchises and contracts made previous to the existence of the State Board of Public Utilities and contrary, this Council believes, to Section 10, Article 1, of the United States Constitution which says that "No state shall pass an ex post facto law, or law impairing the obligations of contracts."

Upon such a fundamental principle of constitutional right and free government, subject to constitutional principles, this and many other municipalities of the state have long stood, contending for the rights of which they have been stripped, and protesting against the wrongs that, in violation of franchises and contracts, have been forced upon their citizens. All this was long before there was any thought of making, one way or the other, a party question, or a controversy or contention in any political convention in this state. It is not a party question but one of fundamental principle and we hold that our position is right and will be adhered to regardless of factions or partisanship, or who may be for or against it.

Let us see how some of the cities in the state of Illinois regarded these so-called contracts and constitutional rights, long before any Public Utilities Commission was thought of.

November 9, 1882, the City Council of Danville passed an ordinance granting the Danville Water Company the right of constructing and maintaining water works, and of using the streets of the city for that purpose for the term of thirty years. By the same ordinance the City agreed to pay the water company as hydrant rental for 100 fire hydrants for the term of thirty years, at the rate of $75 each per year. It was further provided that hydrants in excess of 100 should be at the rate of $62.50 each per year for the next forty hydrants; and for all in excess of 140 the rate should be $50 each per year.

On January 17, 1895, the City Council of Danville passed an ordinance reciting that the rates theretofore charged as hydrant rental were excessive, and that from and after May 1, 1895, the rate for the first 140 hydrants should be $50 each, and proportionately lower rates should be charged for additional hydrants.

The City contended that the rates fixed in the last mentioned ordinance were just and reasonable, and that its indebtedness to the water company should be computed upon the bases of the rates prescribed in said ordinance.

The Water Company contended that the ordinance of November 9, 1882, fixing the higher rate for a period of thirty years constituted a valid contract between it and the City; that the subsequent ordinance of January 17, 1895, which provided for a substantial reduction in water rates, was unconstitutional and void. Please note the contention of the City of Danville and the Water Company in this instance as compared to the resolution adopted by the City Council of Quincy, Illinois, protesting against the orders of the Public Utilities Commission of Illinois issued in pursuance of the Act. How it comes home to us. It depends upon whose ox is gored as to whether ordinances passed by cities for fixing rates constitute valid contracts and whether any variation from same is unconstitutional.

The Water Company challenged the power of the City Council of Danville to fix rates other than those fixed in the ordinance of November 9, 1882, and invoked the aid of the courts. The Illinois Supreme Court in deciding this case (City of Danville vs. The Danville Water Company, 178 Ill., 299) on February 17, 1889, at page 312, said:

There was to be reserved to the city council the power to fix the rates by ordinance at such figures as should be fair and reasonable. If the rates were to be fixed by ordinance, they could only be fixed by such ordinance as was legal and whose passage was within the power of the council. *A legislative body cannot part with its powers by any proceedings, so as not to be able to continue the exercise of such powers.* It has no *authority even by contract to control and embarrass its legislative powers and duties.* (Greenhood on Public Policy, p. 317; Cooley's Const. Lim. p. 206; 15 Am. & Eng. Ency. of Law, p. 1045; 1 Dillon on Mun. Corp. sec. 443.) What might be proper for a city this year might not be proper the next year. It is impossible to determine with absolute or even tolerable certainty what changes a few years might work in the character and reasonableness of rates to be charged for water supply. No contract is reasonable, by which the governing authority abdicates any of its legislative powers, and precludes itself from meeting in a proper way, emergencies, or occasions that may arise. "These powers are conferred in order to be exercised again and again, as may be found needful or politic, and those who hold them in trust today are vested with no discretion to circumscribe their limits or diminish their efficiency, but must transmit them unimpaired to their successors. This is one of the fundamental maxims of governments; and it is impossible that free government with restrictions for the protection of individual or municipal rights could long exist without its recognition." (Gale v. Kalamazoo, 23 Mich. 354; Millikin v. County of Edgar, 143 Ill. 528.)

This same case was twice again appealed to the Illinois Supreme Court on practically the same set of facts, and the opinion of the Court was adhered to in the above case. (City of Danville v. Danville Water Company, 180 Ill., 235; Danville Water Company v. City of Danville, 186 Ill. 326.)

An appeal was finally taken by the Danville Water Company to the Supreme Court of the United States where the decision of the Illinois Supreme Court was affirmed. (Danville Water Company v. City of Danville, 180 U. S., 619.)

About this time two other cases in Illinois received the attention of both the Supreme Court of Illinois and the United States Court. Rogers Park Water Company v. John B. Fergus (decided February 17, 1899, the same day as the original Danville case), 178 Ill., 571., and the Freeport Water Company v. City of Freeport (decided June 21, 1900) 186 Ill., 179.

In these two cases the questions presented and decided were substantially the same as those passed upon in the Danville case supra. The Illinois Supreme Court adhered to its decisions in the Danville water cases. These cases were then appealed to the Supreme Court of the United States where the judgment of the State Court, in each

case, was affirmed. (Rogers Park Water Company v. John. B. Fergus, 180 U. S., 624, and Freeport Water Company v. City of Freeport, 180 U. S., 587.)

As to the case of the Rogers Park Water Company the author happens to have personal knowledge of this case, having located in Rogers Park, Illinois, in 1891, and still residing there. It was then a municipality with its own local government. About 1888 it granted to the Rogers Park Water Company a so-called contract franchise for a term of thirty years, in which the company was permitted to meter all consumers and for domestic purposes charge at the rate of 40 cents per 1000 gallons for water furnished.

After the water works was installed and other improvements were put in, such as sewers, pavements, etc., the territory settled quite rapidily. Consequently the Water Company prospered to a fair degree, and about 1896 or 1897 the company charged domestic consumers about 25 or 30 cents for 1000 gallons, an amount substantially less than the ordinance rates. About this time one John B. Fergus, a resident of Rogers Park, then a part of Chicago, by annexation, in 1893, formed an association composed of a large number of consumers of the company for the purpose of contesting the rates charged by the Rogers Park Water Company on the grounds they were excessive and unreasonable. Through counsel employed they induced the City Council of Chicago to pass an ordinance fixing the rates to be charged by the Rogers Park Water Company, the same as those charged by the City of Chicago, very much less than those of the company. This action was challenged by the Water Company and relief was sought in the courts, with results heretofore set forth, namely, that the City had no power to make a contract to fix unalterable rates for a term of years, but could enter into an agreement with the Water Company whereby "the supply could be made for the entire term, but the price is to be determined from time to time, and the rates to be settled by the rules of common law."

When the Rogers Park case was finally settled by the United States Court, Mr. Fergus was heralded as a great public benefactor. The right was established on the part of the public that franchise ordinances notwithstanding to the contrary, a state agency had the right to fix just and reasonable rates from time to time as the case may be. The author remembers a talk with H. E. Keeler, present here and a member of this Association, during the litigation in which Mr. Keeler stated:

I have a contract expiring in 1918, which must be carried out to the letter, as to rates, if the company insists, and if the people do not behave themselves, the company will charge the full contract rates.

I shall now call your attention to more recent decisions of the courts some of which were based upon litigation growing out of orders entered by the Public Utilities Commission of Illinois. State Public Utilities Commission ex rel Harley B. Mitchell, et al, v. Chicago & West Towns Railway Company, et al, 275 Ill., 555. In this case the Chicago and West Towns Railway Company and others appealed from an order of the Public Utilities Commission dated October 15, 1914, directing said companies to return to the rates and fares in effect on July 1, 1913, which were the rates permitted to be charged by authority of the municipalities served, until such time as the Commission could determine and fix the just and reasonable rates and fares. The Commission entered this order because it was shown that the railway companies had increased their rates on December 31, 1913, which was contrary to Section 33 of the Public Utilities Commission Act. The Illinois Supreme Court held that this provision of the Act was void, and that the law did not become operative until January 1, 1914; that until said law went into effect there was nothing to prevent the appellants from increasing their rates.

It was farther contended by the Company in this case that the provisions of the Public Utilities Commission Act under which the Commission was authorized to regulate the rates of a street railroad were in violation of Section 4 of Article 11 of the State Constitution. In disposing of this contention, the court said:

The Public Utilities act does not violate Section 4 of Article 11 of our constitution. That provision is simply a limitation of the general powers of the legislature, and in one particular, only. It provides, in substance, that the legislature may not grant the right to construct and operate a street railroad within a municipality without requiring the consent of the local authorities having control of the streets or highways proposed to be occupied. That section of the constitution does not, by implication or otherwise, attempt to divest the State of its paramount authority and control of streets and highways. (*Chicago and Southern Traction Co.* v. *Illinois Central Railroad Co.* 246 Ill. 146.) It is equally clear that that section of the constitution does not deprive the legislature of its powers to fix rates for such companies. Section 34 of article 4 of the constitution has no bearing whatever on the question of the authority or power of the State to fix rates for a street railway. That section specifically provides that nothing therein contained shall be construed to repeal, amend or affect Section 4 of Article 11 of the constitution.

In case City of Chicago et al v. Wm. L. O'Connell et al, 278 Ill., 591, and subsequently sustained by the United States Court, the Illinois Supreme Court said:

> It is true that a municipality cannot contract away the right to exercise the police power to secure and protect the morals, safety, health, order, comfort or welfare of the public, nor limit or restrain by any agreement the full exercise of that power. We have accordingly held that a city cannot contract away its right, under the police power, to fix reasonable rates to be charged by a public utility furnishing water to the city and its inhabitants. (Rogers Park Water Co. v. Fergus, 178 Ill., 571; City of Danville v. Danville Water Co. 178 id. 299; Freeport Water Co. v. City of Freeport, 186 id. 179.)

In case of Charles A. Hite v. Cincinnati, Indianapolis and Western Railroad Company et al. 284 Ill. 297, in which it appears that on March 20, 1900, Charles A. Hite and wife conveyed a strip of land in Coles County to the predecessor of the Cincinnati, Indianapolis and Western Railroad Company, the consideration being an agreement by the railroad to give Hite, his wife and son free transportation during their natural lives, upon all trains carrying passengers over the railroad. The railroad carried out the provisions of the contract until December 31, 1915, when it refused to issue further passes contending that the issuing of said passes violated Section 37 of the Public Utilities Act.

Hite contended that this Act is not valid as applied to the contract in question, as it is contrary to the provis ons of the Federal Constitution which forbids any state to pass a law impairing the obligations of a contract. In disposing of this contention the Court said:

> The Public Utilities act was passed by the General Assembly in its exercise of police power (*City of Chicago v. O'Connell*, 278 Ill. 591) *All contracts, whether made by the State itself, by municipal corporations or by individuals, are subject to be interfered with or otherwise affected by subsequent statutes enacted in the bona fide exercise of the police power, and do not, by reason of the contracts clause of the Federal constitution, enjoy any immunity from such legislation.* (12 Corpus Juris, 991, *Manigault* v. *Springs*, 199 U. S. 473; *Union Dry Goods Company* v. *Georgia Public Service Corp.* 142 G. A. 841.) The reason for this rule is thus well stated in *Manigault* v. *Springs, supra:* "It is the settled law of this court that the interdiction of statutes impairing the obligation of contracts does not prevent the State from exercising such powers as are vested in it for the promotion of the common weal or are necessary for the general good of the public, though contracts previously entered into between individuals may thereby be affected. This power, which in its various ramifications is known as the police power, is an exercise of the sovereign right of the government to protect the lives, health, morals, comfort and general welfare

of the people and is paramount to any rights under contracts between individuals. Familiar instances of this are where parties enter into contracts, perfectly lawful at the time to sell liquor, operate a brewery or distillery or carry on a lottery, all of which are subject to impairment by a change of policy on the part of the State, prohibiting the establishment or continuance of such traffic, in other words, that parties by entering into contracts may not stop the legislature from enacting laws intended for the public good." The condition contained in this deed was therefore subject to such regulation as might thereafter be made by the State in the exercise of its police power. Appellant dealt with the railroad company knowing that it was a public utility and that any contract made with it relating to its service was subject to alteration or abrogation by the State in its exercise of that police power.

In one of the recent cases decided by the Illinois Supreme Court on October 23, 1920, Maclay Hoyne v. The Chicago and Oak Park Elevated Railroad Company, 294 Ill. 413, in which the right of the Elevated Railroad Company to increase its passenger fares from 5 cents to 6 cents for each passenger was challenged, at page 417 the Court said:

The Supreme Court of the United States, in Home Telephone Company v. Los Angeles, 211 U. S. 263, has stated it as the settled doctrine of that court that the State may authorize one of its municipal corporations to establish, by an inviolable contract, the rates to be charged by a public service corporation or natural person for a definite term not grossly unreasonable in point of time, and that the effect of such a contract is to suspend, during the life of the contract, the governmental power of fixing and regulating the rates. It is further stated, however, in that case, that for the very reason that such a contract has the effect of extinguishing pro tanto an undoubted power of government, both its exercise and the power to make it must clearly and unmistakably appear and all doubts must be resolved in favor of the continuance of the power. It is the settled doctrine of Illinois that neither the State nor our constitution has given cities and villages, or any other municipality in this State, the right or power to establish by such a contract the rates to be charged by railroad companies, whether street railways or railroads organized under the general Railroad act. (P. 417, 294 Ill.)

At pages 420 and 421, the Court further said:

The result of our holding being that neither the constitution of this State nor the legislature in any act has given to the city of Chicago or to any other city of this State the authority to make an inviolable contract with any street railway or any railroad company with reference to the rates of fare which such companies shall charge passengers, it follows that the city of Chicago's contract with appellees with reference to fares to be charged by them is not binding on the State. As against the State's right to fix the rates of fare for appellees through the commission such contract has no binding force. (De-

troit v. Detroit Citizen's Railway Co. 184 U. S. 368). To hold otherwise would be, in effect, to oust the State of one of its sovereign prerogatives. Section 23 of article 4 of our constitution, providing that the General Assembly shall have no power to relieve or extinguish in whole or in part, the indebtedness, liability or obligation of any corporation or individual to this State or to any municipal corporation therein, is no bar to the legislature asserting its right to regulate and fix rates for railroad companies. Giving the words "liability and obligation," used in that section, their broadest meaning, the provision would then not have the effect to make valid and binding, as against the State, the rates of fare established by the city of Chicago and appellees in their contracts. The liability or obligation spoken of in that section of the constitution only has reference to liabilities and obligations which the corporation and the municipality have the legal right and power to make, not only as between themselves but also as against the right of the State to interfere. We cannot interpret this provision of the constitution to give cities the right, by contract, to establish rates for railroad companies when the same constitituion in other sections has vested this right solely in the legislature. For the same reason it is equally clear that the provisions of the State and Federal constitutions providing against the passage of laws by the State impairing the obligation of contracts are not applicable to the contracts in question. (Pages 420 and 421, 294 Ill.)

In case The Chicago Railways Company v. The City of Chicago (292 Ill. 190) in which the City of Chicago was urging that the settlement ordinances passed in 1907 constituted valid contracts with the Street Car Companies as to rates of fare, the Illinois Supreme Court said (page 195):

A question argued at length is whether the General Assembly, acting through the State Public Utilities Commission as its authorized agency, may lawfully change the rate of fare fixed by contract between a municipality and a public utility, such as a street railway corporation. That question was recently given full consideration upon the same authorities here cited and relied upon, in the case of Public Utilities Commission v. City of Quincy, 290 Ill. 360, and it was there held that the General Assembly has such power. It was there determined that the power to regulate rates to be charged by a public utility is vested in the General Assembly, that the General Assembly has never conferred upon any municipality power to make inviolable contracts for rates for a public utility; that such power of a municipality is not to be implied from authority granted to control streets and regulate the use thereof by public utilities (292 Ill. 195).

The fact is that Illinois was the pioneer in establishing the law as to the power of the State to regulate rates. In the celebrated case Mann v. People 69 Ill. 80, affirmed by the United States Court, 94 U. S. 113, it was held that the power to fix and regulate rates as to public utilities was a common law, one inherent in the State.

The recent case of Union Dry Goods Co. v. Georgia Public Service Corporation, 248 U. S. 372, related to the right of a private corporation, empowered to contract in its business without any enabling act of legislation, to make a contract for an apparently reasonable time for service by a public utility. By the contract the Public Service Corporation agreed to furnish electric light and power to the dry goods company at its place of business in Macon, Georgia, for five years at stipulated prices, which the dry goods company agreed to pay. During the time the Railroad Commission fixed higher rates for the service and the question considered was whether the rates fixed in the exercise of the police power suspended the contract. The decision was that they did and the court quoted from Hudson County Watêr Co. v. McCarter, 209 U.S., 349 that "one whose rights, such as they are, are subject to state restriction can not remove them from the power of the state by making a contract about them."

The United States Court also quoted from Atlantic Coast Line Railroad Company v. Goldsboro, 232 U. S. 548, that:

> It is settled that neither the "contract" clause nor the "due process" clause has the effect of overriding the power of the state to establish all regulations that are reasonably necessary to secure the health, safety, good order, comfort, or general welfare of the community; that this power can neither be abdicated nor bargained away, and is inalienable even by express grant, and that all contract and property rights are held subject to its fair exercise.

From a legal standpoint there was never a proposition of law, as to the rights of the state through its police-power to fix and determine just and reasonable rates or the duty of the members of the Public Utilities Commission under their oath of office, more definitely settled.

Thus far only the legal phase of the problem has been taken up. There are other phases which may be discussed with profit.

Reverting again to the resolution adopted by the City Council of Quincy, Illinois, the following facts are at least interesting:

May 19, 1914, the Quincy Gas, Electric and Heating Company made formal application to the Public Utilities Commission of Illinois for authority to change its rates for gas service in the city of Quincy, Illinois. July 7, 1914, the said city of Quincy (afterwards designated the petitioner in the proceeding) filed with the Commission a cross-petition and complaint among other things alleging

That the present rates for gas and electricity and the proposed rates for gas in the said city of Quincy are unjust, unreasonable, discriminatory, and preferential; and praying (5) that the Commission will make the necessary and proper investigation to determine what shall constitute just, reasonable, non-discriminatory, and non-preferential rates . . . . and enter an order fixing such just, reasonable, non-discriminatory and non-preferential rates, and requiring the observation thereof.

July 14, 1914, the company filed its answer to the cross-petition and complaint alleging among other things that:

But it is denied (4) that the rates for gas and electricity in effect in the said city of Quincy are in excess of the just and reasonable rates, (5) that the schedule of rates now in effect is discriminatory and preferential.

March 1, 1916, the company filed a further reply to the cross-petition and complaint filed by the city of Quincy, Illinois alleging among other things that

On April 5, 1911, the city of Quincy enacted an ordinance granting to the Quincy Gas, Electric and Heating Company, respondent herein, permission to construct, maintain, and operate an electric light, power, and heating system in the city of Quincy, for a period of thirty years, and providing a schedule of rates to be charged for such service and the manner in which such rates, from time to time, might be changed, ... (9) that in keeping and performing the various covenants and agreements contained in the said ordinance agreement, the respondent has relied upon the said ordinance agreement constituting a valid, binding, and legal contract between the said city of Quincy and the respondent, and that the said city of Quincy has received and accepted the benefits arising from the said performance and the expenditures of the said large sums of money, (10) that the respondent has at no time consented that the rates charged by it for electric current furnished said city of Quincy and its inhabitants shall be reduced below the schedule of rates filed with this Commission on February 10, 1914, (11) that the rates charged by the Quincy Gas, Electric and Heating Company for electricity are not excessive rates, under the said ordinance agreement, (12) that, in view of the terms and conditions of said ordinance agreement, this Commission has no jurisdiction to investigate and determine the rates to be charged by respondent, and that only a court of law or equity has such jurisdiction, ... (16) and that, until the said ordinance agreement is amended as aforesaid and the respondent is reimbursed by the said city of Quincy as aforesaid, this Commission has no jurisdiction to investigate and determine the rates of charge to be made by respondent for electricity furnished the said city of Quincy and its inhabitants, nor has the Commission authority to compel respondent to reduce the rates provided for in the said ordinance agreement unless consented to by the respondent, and that the said act entitled 'An act to provide for the regulation of public utilities' is, as to

respondent, unjust, unreasonable, confiscatory, void, and in violation of section 1 of the Fourteenth Amendment and section 10 of Article 1 of the Constitution of the United States. (I. P. U. C. V 4, PP 423, 424, 425 and 426.)

At the expense of repetition and in order to present the picture vividly, the resolution adopted by the City Council of Quincy, Illinois is again quoted:

This Council has repeatedly and unanimously declared itself in favor of municipal self-government in the matter of granting rights and privileges belonging to the people of a municipality and against the arbitrary annulment of the municipal rights in franchises and contracts made previous to the existence of the State Board of Public Utilities and contrary, this Council believes, to section 10 article 1 of the United States Constitution which says that "no state shall pass an ex post facto law, or law impairing the obligation of contracts."

Please note that in 1916 before this country was materially affected by the "World's War" the city of Quincy was calling upon the Commission to fix and establish lower rates than those provided by a franchise ordinance. In defense the company urged that the ordinance constituted a contract and for that reason the Commission did not have jurisdiction and that a variation from said ordinance rates would violate the constitution of the United States. When the scene is shifted to 1919 and 1920, by reason of economic conditions brought on by the great war, it became necessary for the Commission to raise rates, in many instances exceeding rates fixed by ordinances, and the city of Quincy shifts its position and claims the rates to be charged are those fixed by so-called contract ordinances and that any annulment of same would violate the Constitution of the United States. The utility companies are not now complaining of the action of the Commission fixing rates exceeding ordinance rates.

It is unnecessary to argue that if the Commission has power to fix rates lower than those set forth in a so-called contract ordinance, if found to be excessive after investigation, the Commission likewise has power to fix rates higher. This should be self-evident to the most skeptical or belated official or individual.

The Commission in disposing of the cross-petition and complaint issued an order on May 7, 1917, Case 2523, I. P. U. C. V 4, p. 423, ordering the company, and the company obeyed the order to place in effect rates substantially lower than those permitted by the city of Quincy. In order to take such action necessarily the Commission was required to hold that rates found just and reasonable by it must

prevail irrespective of those set forth in so-called franchise or contract ordinances.

The Illinois Commission early in its existence, during the term of Governor Dunne, clearly declared itself as to its duty and power to fix and establish just and reasonable rates, contract ordinances notwithstanding to the contrary.

In case Cook County Real Estate Board v. Chicago Surface Lines et al, case 3281, I. P. U. C. Vol. 2, p. 291, passed September 29, 1915, the Commission held that (p. 294)

> The Commission was given full jurisdiction in the Illinois Public Utilities Law over all questions involving the service of Public Utilities. In the exercise of its power under the law, the Commission from all the evidence in the case believes that trailers should be operated by respondents and the order will so provide.

This order was confirmed by the Illinois Supreme Court and that court sustained by the United States Court. (City of Chicago et al v. Wm. L. O'Connell, 278 Ill., 591). This order of the Commission heretofore referred to, directing the operation of trailers was in direct conflict with the settlement ordinances of 1907.

In case of Polo Mutual Telephone Company and the intervening petition of the City of Polo, Illinois, No. 3121, I. P. U. C. Vol. 3, p. 31, decided December 23, 1915, Commissioner Yates speaking for the Commission, after quoting many court decisions, held that, page 35,

> In the present case it clearly appears that the legislative department of this state has never divested itself of the power to regulate rates of telephone companies and our conclusion is that this Commission is not bound by the so-called contract entered into between the City of Polo and the Polo Mutual Telephone Company in so far as said contract attempts to establish the rates that shall be charged by said telephone company.

In raising rates during the last few years, the Commission first applied the universal rule laid down by courts "The utility is entitled to a fair return upon the fair value of the property" and the findings established early in its existence as to its jurisdiction versus so-called contract ordinances so clearly settled by the courts.

Regulation came about by reason of insistent demands by the public to correct abuses by so-called monopolies engaged in the utilities field, upon which the public was dependent, but had no effective instrumentality to protect it. The keynote of all regulatory laws is that the public shall receive adequate services at just and reasonable rates.

The fact is that State Commissions were created for the very purpose of breaking so-called contract ordinances. In the pre-war period the public believed that many of the rates authorized by ordinances were excessive and necessarily if the State Commission was to give any relief the rates prescribed by ordinances or otherwise must be disregarded. That part of the public which now accuses the Commission of being contract breakers and corporation tools by reason of disregarding those so-called contracts is responsible for obtaining decisions from various state courts and even the United States courts, as hereinbefore referred to, that the rates prescribed in these ordinances must be set aside when it is determined, as provided by law, that the rates so fixed are unjust, unreasonable, insufficient or excessive. From the point of view of that same part of the public, in the pre-war period the test applied to determine the popularity of the Commission was the extent to which it lowered rates and broke so-called contracts.

Apparently there is a movement on foot to change the laws of this state to the effect that any rates or charges for utility service fixed by so-called contract ordinances shall prevail and remain unchanged during the life of the ordinance. That means the public would be burdened without recourse to pay the rates for the term of the ordinance which may be passed at this time based upon present high prices of labor and material. Suppose a franchise expires now and the utility demands a new ordinance very favorable to itself and greatly to the disadvantage of the public, under the threat of discontinuance of service. Is it not possible under such conditions to have a great wrong forced upon the public without recourse? The street car franchise recently expired in Toledo, Ohio, and the company, in order to compel the city to comply with its demands, removed all of its street cars from the city during the night.

Were the author a large owner of public utility properties, he would urge with all the force within him that the laws of this state should be changed to the effect that all rates fixed by ordinances should prevail during the term of the ordinance. We are now living in an era of high prices for labor and material on account of the great World's war. Prices must come down. How soon and how fast no one knows.

The Supreme Court of this state in the Danville case supra, back in 1899 when times were normal, well said:

It is impossible to determine with absolute or even tolerable certainty what changes a few years might work in the character and reasonableness of rates to be charged for water supply. No contract is reasonable by which the governing authority abdicates any of its legislative powers and precludes itself from meeting, in a proper way, emergencies or occasions that may arise.

The Court of Appeals of New York in passing upon the constitutionality of the New York emergency housing law said (reported in *Chicago Tribune*, March 9, 1921):

Either the rights of property and contract must, when necessary, yield to the public convenience and the public advantage, or it must be found that the state has surrendered one of the attributes of sovereignty for which governments are founded, and make itself powerless to secure to its citizens the blessings of freedom and to promote the general welfare.

Shall the State surrender one of the attributes of sovereignty for which governments are founded, and make itself powerless to secure to its citizens the blessings of freedom by reason of present agitation, largely political, growing out of economic conditions as a result of the great "World War?" There can be but one answer. No.

OPERATING A WATER WORKS PLANT UNDER STATE SUPERVISION[1]

By C. M. Roos[2]

After eight years of state regulation of public utilities in Illinois, there is much discussion of whether or not the law providing for such regulation should remain as it is, or be repealed entirely and we should go back to so-called "Home Rule," or the law should be revised in some manner to correct certain alleged faults. Discussion of utility regulation by those who advocate Home Rule has brought forth expressions from various interests and classes throughout the entire state, which appear to be largely in the majority, favoring a continuation of state regulation as opposed to home rule.

Few questions in Illinois at present are attracting as much attention from commercial organizations, business men, bankers, professional men, municipal authorities and labor organizations as this. In all of this discussion little has been said publicly by the utilities themselves. It is obvious why there should be hesitation on the part of the utilities in going on record in a discussion of this character, because past history proves that there is a tendency on the part of the public to look upon statements by public utilities with a certain suspicion, and to refuse to accept same in the good faith which should exist if coöperation and best results for all interests concerned are to be obtained.

But have we not reached the time when common sense, good business for all concerned and the best interests of the general public demand that the experience, opinions and advice of public utilities be heard in the discussion of this and other similar utility questions which vitally effect the public? Certainly no other interests are better qualified to participate in the discussion of public utility prob-

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lems than the public utilities themselves. The woeful lack of intelligent understanding on the part of the general public of some of the vexing utility problems of today is largely because the utilities have hesitated to discuss these problems frankly and openly and to take the people into their confidence.

This entire situation is largely due to the attitude which the utilities have taken toward the general public. Utilities have not talked to the people as freely as they should. The utility business is the most vital business in any community, having a more direct bearing on the community welfare, progress and convenience than any other class of industry. There are few classes of business more dignified and contributing more to the comfort and welfare of man and which are today operated in better faith than the public utilities. Utilities have much to talk to the people about, many interesting and vital things about the business to explain, and the sooner the general public knows the real facts about the utility business, coming frankly and in good faith from the utilities themselves, the easier will it be to wisely and successfully solve some of the problems with which the utilities struggle today.

If the public really knew conditions as they exist today in the public utility business there would be little difficulty in solving our utility problems, the utilities would be in a position to do financing to better advantage, confidence in utility securities would not be shaken and utilities would be in a position to make needed improvements and extensions, all of which would be directly to the advantage and interest of the consumers and would contribute directly to community development and the reëstablishment of general business confidence.

Public utility educational campaigns are needed and the burden of conducting them rests upon the shoulders of the utilities. Is it not true in practically every community that the public criticises and openly attacks its public utilities more freely than any other class of industry within the community, and yet only a very small percentage of the citizens of a city will ever take the time and enough direct interest in their utilities to even visit the plants, see how the work is done or talk with the managers and learn at first hand some of the things they should know about this most vital part of their community life and existance?

A recent personal experience in talking with a prominent business man who has the direct management of a large industry, illustrates

how grossly is the position, in which the utilities have been thrust during recent years, misunderstood by men whose intelligence would not permit such an attitude if they knew the inside of the utility business. In commenting on a recent increase in rates for water, after hearing the explanation that the last year's business resulted in an operating loss of about $12,000, the business man said: "Your company's investment in this city represents approximately $500,000 and my judgment is that it could not be duplicated for anything like such an amount. You show an operating loss of $12,000 for one year on a half-million dollar investment. I know of a business in this city with an investment of $100,000 which showed an operating loss last year of more than $12,000. Why should you find fault with such a small loss with such a large investment as you have, as you should be better able to stand it than the $100,000 business?" Such comment to the utility man is really amusing, but it must be regarded seriously, as the man who said it was serious about it and he represents an intelligent class in the community. This man does not stop to think that the $100,000 business to which the referred earned profits of several times its capitalization during the fat years of and following the war, and now has a reserve in actual cash sufficient to withstand the strain of many years of loss at the rate of $12,000 per year. In contrast with this condition, the utility business with five times the investment not only failed to show a return on the basis of its large investment, but in most cities showed a loss during most of the period of high commodity prices, and now is not only without a cash reserve, but has its credit impaired and an extremely low market for its securities.

The public utility educational program should include,

1. Interesting members of commercial organizations, city councils, women's clubs and civic and labor organizations in making careful inspections of the utility plants. These visits should be made in groups and instructors at the plants should explain details of operation, maintenance, expenses, etc.

2. When at all practicable, local citizens should invest financially in their local utilities. The people themselves can do much to make their utility investments the safest and most desirable to be found, and as a result they will not only profit financially directly from their investment, but indirectly in service rendered by the utilities and in the ability of the utilities to keep pace or set the pace for community development and expansion.

3. Local boards of education should be led to see the importance and necessity of having pupils of all grades in the public schools study their local utilities. In most cities the utilities could provide lectures periodically to the school children, and also to the school instructors who in turn could teach the subject in connection with with their regular class studies.

4. Newspaper advertising in the form of heart to heart talks with the people. Enclosure slips in local mail telling the consumers about their utilities.

5. It should be known in the community that questions and complaints or criticism about service, etc., are solicited by the utilities instead of discouraged, so that consumers will not hesitate to go direct to the utilities about any matter in connection with their business in the community.

Education of the public should be along three distinct lines, viz.:

1. The people should take a real and direct interest (financial if possible) in local utilities, familiarizing themselves with the business to the extent possible.

2. To select capable, well qualified men to represent them in their government, local and otherwise, regardless of political affiliation and to trust to the judgment of experts in deciding questions of a technical or professional character.

3. To be less hasty in openly criticising constituted authority unless or until the basis for criticism is well and intelligently established. Unless the attitude of our American people toward constituted authority changes it will soon be difficult to persuade highly qualified men to serve in public office. Lack of confidence in constituted authority destroys the very basis of sound government and the results are evident on every hand.

We are living in an age when the people demand control and rule as never before. It appears to be the popular movement among thousands in all nations. The rights of the people must be defended and preserved, as this is a country of and for the people and no one has any authority whatever, civil or otherwise, to deprive any citizen, who respects the laws established by the majority, of his rights as a citizen. But rule or control or regulation by the people does not mean that safety, economy and efficiency in all channels of civic and industrial activities can be secured by direct supervision or regulation by the masses, who cannot be expected to be qualified to pass wisely on all phases of community life and industry. Thus the

judgment of a doctor of medicine would scarcely be expected to be good in deciding a technical question in connection with the regulation of a water works. The same can be said of many other classes of citizens without in any sense reflecting upon their intelligence.

Rule by the people, in proper, common-sense form, means that they select or provide those whose business it shall be to represent the people impartially in the various positions or offices, and who shall be considered as properly constituted authority in their respective positions. It is presupposed that such constituted authority shall either be well qualified to pass intelligently on the questions in their line, or who will proceed to qualify for the work by familiarizing themselves thoroughly with it.

The water works business is unique in many respects as compared with private industries. It is by nature a monoply in its community which it serves. It is to the interest of both the consumer and the operator that it be a monopoly. Duplication of investments in public water supply in any city invariably results in the necessity of finally consolidating the systems, thus throwing upon the consumers the burden of supporting a larger investment than would otherwise be necessary.

A water works is unique in that the investment in it is, or should always be, of a permanent character. The very nature of the business requires this. Our limited franchises (a relic of Illinois home rule) prevent economical financing of permanent investments in water works and also prevent private utility corporations from installing in communities as high type equipment as otherwise could be provided. Attempts by local communities to fasten upon water works utilities iron clad contracts in the form of franchises, and at the same time demand immense investments in equipment, the protection of which depends directly upon bargaining again at the expiration of the franchise with local authorities who, though otherwise intelligent men, may have no technical knowledge of water works and cannot be expected to have, cannot but result in working havoc at no distant date the truth of which will certainly soon dawn upon many of our Illinois cities, much to their sorrow.

A water works plant is unique in that it is expected to operate continuously whether costs of supplies are high or low, regardless of labor troubles or transportation difficulties, whether the business is profitable or not, whether the company's credit is good or bad, and when repairs are difficult and expensive to make on account of

inability to cease operations for a period. In addition to all of this, the plant is supposed to be operated on the basis of a bare legal interest rate of return on its investment as its maximum return, with no guarantee against losses. No profit is supposed to be figured in water works business. An interest rate of return on an investment in an industry cannot be considered as profit. To insure holding the return to utilities at the rock bottom or below, the public stands by dictating the rates to be charged for service.

Now in contrast with a water works plant, note that a private industry has the sky as its limit for profit and when business is bad it closes its doors and lays off its employees, thus cutting down expenses. It ceases operations at will to make repairs at ease and economically. Its machinery and equipment usually operate only about 8 or 9 hours per day and 6 days per week, which gives the mechanical department ample opportunity to do emergency work to good advantage. It markets its securities to much better advantage than a water company possibly can. It has an unlimited field for development. Finally, it is its own boss in the sense that it has no public regulation of its rates or prices for its product.

These statements as to conditions under which a water works utility must operate as compared with a private industry are true in a sense whether it is under state regulation or home rule. In both cases it is public regulation by the people. The question under discussion by so many in our state is which method of regulation is to the best interests of all concerned.

The public utility business by nature should be, and must expect to be, subject to public regulation. The only real fault or complaint along this line which utilities should file is that it is discriminatory and grossly unjust that the public should "regulate" utilities, which means keeping profits down to rock bottom and far below in many instances, and at the same time not "regulate" the control of the state's natural resources and necessary commodities upon which utilities must depend to operate their plants.

Public control of utilities and failure to control the business which furnishes utilities with necessary operating supplies has resulted during the last few years in the utilities' already deflated purse becoming leaner and leaner, with its contents filling the purse of private industry in enormous profits. The State Public Utilities Commission is not at fault in this. The fault lies in the provision by our government for regulation of one class of business while another class

is earning large profits from money from the first class, all unmolested, because no authority has been provided to regulate certain private industries.

This discussion is not presented for the purpose of registering an objection on the part of a public utility against public control of its business. Its object, in part, is to state that both home rule and state regulation of utilities are control by the people, of which control so many are jealous. Its object, further, is to call attention to the fact that the general public does not realize that the public utilities have suffered enormously in depleted earnings and heavy losses during the last few years, when other industries were growing fat, and that the small increases in rates authorized from time to time recently by the State Public Utilities Commission were absolutely necessary in practically every case to barely keep the utilities alive.

The people of our state do not appear to remember that from January 1, 1913, to January 1, 1917, the State Public Utilities Commission lowered rates for utility service throughout the state to the extent that over $5,000,000 were saved to the consumers during that period.

The general public apparently does not realize the tremendous significance of the fact that during the last few years the increase in the cost of money to the public utilities has been three times that to manufacturing industries, and that the only way capital can be secured for our utilities is in the open market in competition with these other more attractive securities.

Our people fail to realize the significance of the fact that in the United States today the investment in public utilities, exclusive of railroads, amounts to approximately $15,000,000,000, of which about $1,250,000,000 is in Illinois, and that this immense investment has not been made by a favored few, but by the people themselves who hold utility securities. In Chicago alone, $565,000,000 is invested in utility companies, being more than twice as large as Chicago's investment in its own operations. These figures represent book value. Reproduction of our utilities as of today would show a much larger investment than is indicated by the figures here submitted.

The general public does not realize that it is benefited directly and otherwise more by the capital invested in its public utilities than in any other enterprise within its borders, yet the tendency on the part of the public generally is to abuse or fail to appreciate capital invested in its utilities more than in any other industry.

Those who are opposing state regulation do not know the great value and importance of having uniform systems of accounting, well established standards for service, equipment, etc., for all the utilities in force throughout the state, all of which have been brought about by state regulation and which cannot be provided or maintained otherwise.

The general public is woefully ignorant, indifferent or forgetful of all of this largely because utilities have failed to frankly talk to the people as they should.

While the public utilities as a class have hesitated to go on record in expressing an opinion about state regulation, yet it is a fact that many utilities have chafed under the apparent delays in securing absolutely necessary relief through the State Utilities Commission, and when relief would finally come, it would often be inadequate to provide for increases in operating costs subsequent to the time when applications for increased rates were filed.

Utilities must realize the fact that the State Commission has been dealing with a public sentiment invariably strongly prejudiced against public utilities, which made it difficult for the people to understand the absolute necessity and justice of increased rates for service. The Commission as representative of the people has the people to listen to as well as the utilities. Few communities realize as utilities do that they owe the State Public Utilities Commission a real debt of gratitude for having tided the utility business of the state over the most dangerous and difficult period in history, when commodity prices soared from 100 to 300 per cent above normal, and at the same time holding rates for utility service down to a very small fraction of this increase in general commodity costs.

Though the utilities have suffered greatly during this difficult period, it is a remarkable fact that the state regulatory body has handled the situation without a single case of a utility ceasing to function.

Rates for service seems to be the point around which practically all critcism of state regulation on the part of the general public centers. Illinois has no reason to complain about its utility rates for service, particularly about water rates. The average highest rate for water in Illinois is 0.304 cent and the average best commercial rate is 0.13 cent per thousand gallons, as of January 1, 1921, which is considerably lower than the average rates in other states.

The rate question is secondary as compared with another most serious feature of the utility situation in Illinois, that of shaken confidence in utility securities in the state, largely due to the fact that Illinois continues to make its public utilities the subject of political agitation. Low rates for service, resulting in very small returns on utility investments, are the cause in part for the depression in the utility securities market, but not so much so as lack of confidence in the stability of the investment.

Confidence in utility investment must be restored. The interests of the public will best be served by having it so, regardless of the direct effect it may have on the utilities themselves.

Regardless of the attitude of the public toward state regulation, anything less than state regulation of utilities will mark the complete collapse of the market for utilities securities and thus destroy the very foundation and framework of the entire economic structure.

DISCUSSION

Chairman F. C. Amsbary: Some time ago, it became apparent that something must be done to inform the public in the territory supplied by the Champaign & Urbana Water Company about the difficulties arising in the operation of a water plant. About two dozen articles, each 20 to 30 inches long, were prepared and these are now running once a week in the newspapers. The first article intimated that the company desired to have the public know more about its business, that it wished for the good will of the public, and that it believed this good will could be gained by showing how much money was received and from what sources, how much money was spent and for what purposes, and what were the operating problems and the mechanical and financial difficulties. About six articles along these lines have already been printed. Much of the inspiration for and material in these articles came from Mr. Gwinn's publicity at Terre Haute.

Another important kind of publicity is encouraging the public to visit plants. Several years ago, the public officials and journalists of the two cities supplied by the Champaign & Urbana Water Company were invited to visit its plant. There were 28 of these guests and only eight of them had ever visited the plant before. The visit did the company much good, for those who took part in it realized something of the magnitude of the business and the wide range of problems it presents.

The ignorance of the public on public utility regulation was typified by a recent remark made by an acquaintance, a good, intelligent citizen. He claimed that the local street railway company should pay the city $50,000 for the privilege of operating cars on its streets. He argued that some of the stockholders of the company were wealthy men and could easily afford to make such a contribution to the public funds. It was not easy to convince him that such a charge against the company would not be met from the pockets of the rich stockholders but would be considered by the Public Utility Commission as one of the expenses of the company, to be met by an increase in the rate of fare.

H. E. Keeler: It is possible that Mr. Shaw did not make quite clear what the United States Supreme Court decided in the Rogers Park case. It is true that the court ruled that any city council in Illinois had the right to disregard a contract rate expressed in a franchise, but court also ruled that the city council had no right to enforce by ordinance any rates different from those expressed in the franchise which would not yield a reasonable return on the investment actually made in the property. The court made it very plain that a city council had no right to enact rates which did not provide an adequate return. In the Rogers Park case, the city council of Chicago undertook to change by ordinance the rates charged by the Rogers Park Water Company, which had voluntarily reduced its rates to just one-half of those stated in the franchise. The courts held, in substance, that the rates charged were reasonable, and the only way to give the citizens lower rates was for the city to purchase the company's plant, as provided for in the franchise, which course was followed by the city council.

Dow R. Gwinn: Some years ago, the city of Quincy, Ill., paid the local water company $200 a hydrant, a price fixed by contract. The city finally refused to pay this rental for three years, when the arrears amounted to $48,000, and the company brought suit for the money. The Illinois Supreme Court ruled that as the city was in debt beyond the constitutional limit at the date it made the contract, the latter was illegal.

Formerly water companies were inclined to take care of their business to suit themselves, without much regard to public opinion. That day has gone by; it will never come back again. In Terre

Haute, the water company likes to get all the good publicity possible. It has invited the medical society to its plant and explained the method of purifying the water. It was worth a good deal to the company because there are persons who believe more thoroughly in their physicians than they do in their ministers. Then the Manufacturers' Club and the Rotary Club were similarly invited to become familiar with the plant, which has a very nice park where guests can be entertained easily and enjoyably.

The Terre Haute Water Works Company has also run a series of "water talks" in the newspapers. This was started to overcome opposition to water meters, and was successful in that respect. These advertisements have been used ever since when the company had something to say about its business. The largest advertisement was a double-page spread in one issue of a daily, but when it was used newspaper space did not cost as much as it does now. Advertising is expensive but well worth all it costs because it enables a company to state its case to the public in a better way than is afforded by any other means. The sentiment it creates toward the company is favorable. Recently the Terre Haute Company had a case involving an increase of rates before the State Utilities Commission. The Terre Haute Chamber of Commerce represented at the hearing that the increase met with local approval, for the city could not prosper unless its utilities prospered. The delegates of the Chamber of Commerce pointed out that as the city grew extensions of the water mains must be made, and these could only be made if the company was prosperous. The hearing was held December 29 and on December 31 the Commission gave the company all it had asked. This was very largely the result of publicity.

R. B. Wallace: The only trouble with papers like that by Mr. Roos is that they appear about twenty years too late. The City of Council Bluffs would probably never have taken over the water plant, for example, if the company that owned it had come out publicly and told about it. Municipal ownership of the plant does not lessen the importance of publicity, however. There has been no change in the rates in Council Bluffs for ten years. The city has been growing rapidly and large industries have located there. It became necessary to extend mains to distant parts of the city, double the reservoir capacity and make other improvements. The City Council and Mayor agreed to ask the voters to approve a $300,000

bond issue for these purposes at the November election. It was a bad time to ask for money and probably few of the men who consented to the proposition thought the bond issue would be carried. So the Water Board decided to carry on a publicity campaign. On a map of the city, there was shown in one color all the mains laid by the company and in another color the mains to be laid by the city. This map was sent to everybody in the city with a letter explaining what was to be done with the money. There was considerable opposition, but the newspapers supported the bond issue without being paid to do so, the project was advocated in talks before influential local associations, and as a result of this publicity the vote was 8400 to 1200 in favor of the bonds.

The trouble with most publicity is that it is high above the heads of persons it aims to influence. This is particularly true of technical publicity. There was an article printed recently by one of the large manufacturers of electrical apparatus. It was intended to influence water commissioners and such men, but it was so technical that its only interest was that shown in a conundrum; here are the words, what do they mean?

It may be of interest to add that the first $100,000 of the $5\frac{1}{2}$ per cent Council Bluffs water bonds were sold a few days ago at par, accrued interest and a premium.

J. Chris. Jensen: The position of public utilities toward the public has been much like that of the man who went without buying an umbrella during several months of fine weather and then needed one very badly when it rained. For many years running a public utility was an easy matter. It was not difficult to do business with the average city council and to obtain whatever franchises and contracts were needed. When the average public utility obtained its contract, it set a big sign, "Positively no admittance," on the entrance to its plant. There are some of them still in existence but there is no good reason for them. When the Council Bluffs plant was taken over by the city, there was such a sign on its front door. There were also conditions behind the sign that the water commission desired to better before inviting the public to visit the plant. Within a year everything was in good condition and the public was invited to inspect the plant. The water commission began its publicity then. High school pupils are taken to the plant and its operation explained by the officers and commissioners. The Rotary Club, the Commercial Club, and other organizations are invited to make similar visits.

Public utilities generally should get behind this publicity movement and not leave the work to those companies which need an increase in rates. Public support will be desired by every utility sooner or later and it is well to win it before it is urgently needed.

Dabney H. Maury: The intimation by one speaker that collusion between utilities and city councils was formerly customary is hardly justified. The men on the inside of the water works counter average as honest as those who come to pay their bills. During an intimate connection of 19 years with the management of a water company, there was not even a rumor of bribery in connection with its operations. While there may have been cases here and there of payments for votes for franchises, it is probable that in most cases the demand for a bribe was made by some corrupt city official. It is also probable that their demands have been refused far more often than they were paid.

It is true that utilities have been tardy in taking the public into their confidence. There is nothing they can do which will result in more benefit to the public and to themselves than to lay all their cards on the table. Mr. Gwinn is an excellent example of an enlightened utility manager who is now reaping the reward of his intelligent publicity. Nevertheless, it is doubtful if his plant has earned up to date what would be considered a fair rate for an industrial enterprise. Will somebody name a water company which has earned within the last fifteen or twenty years what can be considered more than a reasonable profit for even a few years? There is none in Illinois earning even a half-way fair profit for an ordinary business. Water works properties have not had fair rates in the last fifteen or twenty years. Bonds of water works companies cannot be sold today, although years ago they were considered choice investments. Part of this changed attitude of the public has been due to the arrogant and secretive attitude of some water companies and part has been due to the widespread agitation for municipal ownership. It is these things the utilities must counteract by publicity such as Mr. Gwinn employs.

It is difficult to understand how any man, not influenced by political aspirations or business connections, can deny that a public utility commission is a good thing. It puts the control of rates in the hands of men not directly interested in them. While heavy political pressure and vociferous public clamor may affect the decisions of a com-

mission to some extent, nevertheless the regulation they give is infinitely better than regulation by the municipality itself. One of the great defects of the Illinois law is that it does not place municipalities under the Commission. Municipally owned utilities need impartial regulation just as much as privately owned utilities, so that reasonable standards of service and proper systems of accounting shall be compulsory. Another defect of the Illinois law is that it prohibits indeterminate franchises. The stability of the investment in a public utility is of prime importance. Under any system of regulation the rates to be charged are a function of the cost of the service, and as the rate at which money can be borrowed is a leading factor in the cost of the service, anything which conduces to confidence on the part of the public in the permanence of the investment, such as the granting of an indeterminate franchise, reduces the rate at which money can be obtained, makes it easier for the company to improve its plant, and lessens the cost of the service rendered the consumer.

J. N. Matthews: There have been discussions here about hydrogen ions, franchise rights, and stories have been told, but no one yet has quoted a passage of scripture. So attention is called to this statement in the bible: "By their fruits shall ye know them." That was stated long before the water utility was developed, but it is applicable in our age, One may know nothing about the chemical composition of the sap of a tree or the wood or the bark or the underlying creative principle by which the fruit and blossoms and leaves are moulded, but when the fruit is finally developed he has no trouble in telling a pear from an apple or an apple from a prune; and so it is with the public utility business. The best informed consumer of water service may know nothing about the organization, the lines of authority, or the difficulty the utility has in conducting the sale of its securities, but even the most ingnorant consumer is a judge of whether or not the water is potable or whether he has to carry the water up to the second floor because the pressure is not adequate.

In considering water service we are very likely to consider—both from the public point of view and from the point of view of the consumer—that the service is good if the continutiy is perfect or if the quality is good and if the pressure is good. If we can use the water and if the water is there whenever we want it to use, we ordinarily say the service is good. But if you are left covered with soap under a

shower bath because the pressure became inadequate at that moment, or if you have to carry water upstairs to flush the toilet, the chances are your judgment of the quality of service of that utility will depend on the condition of your kidneys or some other part of your anatomy.

The handling of complaints undoubtedly moulds the public opinion. It is a matter of experience that in a good many localities, where the service, from the standpoint of perfection and as determined by standards that were established by the public utilities commission, is undeniably poor yet the citizens in that city or community will state that they have the best service in the state. That reflects the attitude of the public. It is friendly or unfriendly, depending largely on the success that the company has in satisfactorily disposing of its complaints.

The sign, "Postively no Admittance," that was mentioned here in connection with plants, generating stations, and so forth, is posted in spirit in a good many public utility offices, and the result is that the consumer, if he questions his bill or makes a conscientious effort to learn anything about the utility, is so discouraged by the utility representative with whom he speaks, that he is sorry he ever approached the subject; and to that extent the utility has hurt itself. More than one municipal plant in this state can be traced to the fact that the former company did not satisfactorily dispose of its complaints and did not properly encourage the public to come in and find out about the company's business and learn the operating problems of finance that the utility was confronted with. Many towns in this state have agitated municipal plants because of that fact, although the service in a good many of them was far above the standard in many other communities where the consumers said, "We have the best service in the state."

Through the handling of complaints the utilities have their only opportunity of meeting the public in a good many instances, and the consumer has his only opportunity of coming in contact with the company. A little better insight into the company's business, as explained here, and considerably better care on the part of the utility to give the consumer the information he is after would undoubtedly go a long way towards making better relations with the public and more friendly relations between the city and the municipality, and the agitations against rates which we find in certain localities now would not exist. To talk to the consumer about some of the subjects that have been discussed here—the hydrogen ion or the franchise require-

ments or a discussion of straight line depreciation would mean nothing to him. He wouldn't know whether one were talking about some sort of a disease or a new kind of a soap; but he knows whether the service is satisfactory and he knows whether or not that representative of the public utility he has seen has given him a courteous reply to his question and to his inquiry. That may be the only experience the consumer has had in dealing with that utility. To him it is an individual case; to him it merits individual attention. The complaint man has received a dozen such complaints on the same day and it means nothing unusual to him. He has heard a good many just like it; he is tired of answering those inquiries. To him it is just as it would be to us in our local community to be continuously harassed with the question: "Where is this building?" or "Where is that building." It is none of our business and we are not disposed to make it our business.

The representative of the utility ought to make it his business and he ought to be a man especially adapted to that work. It need not stop with the representative who handles complaints. An invitation to go to a man a little higher up or "Come in and see the manager," has ever created an impression on the public which makes it easier for the utility to develop the relation that is desired. The consumer is very likely to be indignant and aggravated when he presents his problem, and that is unfortunate. It is all the more reason, however, why it is an intricate problem for the company to contend against and all the more reason why the company should put forth a special effort to meet it.

The unsatisfactory relation between the consumer and the public is often a matter of misunderstanding. It is like the case of the American boy visiting in the English family. The English boy at the table asked his father to pass the 'am. The father said, "That is not *'am*; it is *'am.*" The mother kicked the American boy on the shin and whispered: "They are both trying to say *'am.*" It was a misunderstanding, but each thought he or she was right.

There is a limit to which any complaint man or a representative can go. We do not respect any man who allows himself, in the slang expression, to be entirely "walked over." but we do believe that a great deal more forbearance on the part of the company and its representatives would go far toward making the problem easier.

There is another question which is troubling utility commissions and companies alike. It is the matter of main extensions. There

are factors entering into the extensions of water mains that do not enter into the extension of electric and gas service, namely, municipal regulations covering these matters. Water companies are limited, in a sense, in the kind of a main they may install, or when and where they wish to install it, depending on whether or not the city agrees to pay the fire hydrant rental. But making provision for the fact that they are bound in a way by the municipal ordinances or franchises, the matter should be given consideration in order that the utility commission may know the attitude of the utilities toward the subject. There is the question, naturally, of extending temporary mains, which might be small wrought iron pipes, and there is also to be considered the extension of the large mains for fire service purposes.

J. W. McEvoy: A bill has been presented to the legislature of Iowa, with every assurance that it will be passed and enforced July 1, covering the matter of extensions. The bill is drawn up to assess the abutting property, where the extension is made either by petition or by the abutters or where the water department or the city council, or whoever is in charge, deem it advisable to extend the main. In making assessments upon private property the amount shall be calculated upon the cost of laying a 6 inch pipe and where larger pipe is used the difference in cost between such larger pipe and the 6 inch pipe is borne by the water department. The assessments are to be made in the same manner that assessments are made for sewer or street purposes; with an extension to the main, allowing a fifty-foot lot for each connection, the entire cost shall be refunded to the abutter; that is, on a connection with a main and the installation of a meter, and he becoming a life consumer, his entire assessment is refunded to him.

The idea is this: There are a number of people holding property on speculation, unimproved, in the outskirts; there will probably be a small number of petitioners who will build homes and make application for water and sewer. In order to give them water and sewer the company would be required to pass this unimproved property, which would not pay anything toward the improvement nor sign a petition agreeing to take water at any time. It would necessitate the water department or company bearing that expense. The idea is to make the man who would not do anything stand the burden of the cost of the improvement until either he or someone else purchases the property and makes a connection to the main. While such a law will make a little more work for the water department and the

city council, in making the assessment and carrying on the work, it will compel the abutter who refuses to connect to bear the cost of the improvement until such time as a connection is made. There is a provision that the property may be sold for non-payment for the extension of a water main, just the same as for sewer or street improvements.

WALTER A. SHAW: While the Illinois laws do not permit all the things which the Iowa legislature is asked to authorize, yet it is possible in Illinois to pay by special assessment for laying water mains and installing hydrants and valves. In a town buying water from Evanston, all money for the distribution system is raised in this way, because the system is regarded as an improvement. In Maywood, a well and pumping plant were paid for by a bond issue and the distribution system by special assessment. Lake Forest has made arrangements to buy the local pumping plant with the proceeds of a bond issue and the distribution system by the sale of special assessment bonds.

It is impossible to separate service and rates. Lawyers have argued that a utility commission should first give consideration to the adequacy of the rates. They claim that if the service is inadequate the Commission should make it suitable by enforcement of penalties for violation of orders of the Commission. Perhaps this is correct from one point of view, but the distinction is one the people cannot appreciate. The first thing in the public's mind is the service and the treatment it receives. If the service is unsatisfactory and the treatment poor, the public becomes resentful. Under our form of government it is impossible to enforce for long a law obnoxious to the majority of the people. Therefore the utility company and the utility commission have two great, closely correlated fields to cover, service and rates. If the people have the service they wish, then they will agree to pay reasonable rates for it if the full justification for the rates is presented to them. If they do not get the service they desire, there will be public dissatisfaction with any rates.

DOW R. GWINN: The financing of water-main extensions is a pretty big question, particularly with a private company in a city where the local officials are inclined to order extensions without much consideration of their cost. It should not be forgotten that if a company earns a reasonable return on its entire investment, as it is entitled to do, and some of the extensions it has been ordered to make are

unprofitable, then some of the burden of these unprofitable extensions must be carried by consumers to whom they are of no value, which is hardly fair.

In a general way, it may be said that a company should not be required to make an extension unless it will serve a certain number of consumers. If there are about fourteen lots to a block, then there should be at least six connections, and the water main should not be laid until the plumbing fixtures are in the houses served by these connections. It is not fair to ask a water company to lay a water main in a street to help property owners sell their lots. A Terre Haute real estate agent has estimated that a water main in a street increased the value of a lot about $50, which is a very conservative estimate. The method of paying for water mains in large tracts which are being developed for residence purposes has been discussed often. The water mains must be laid to make such large real estate operations successful. The men who get the benefit of the extensions should pay for them. If the real estate operator is paid enough to give a reasonable return on the investment, plus depreciation, plus about 10 per cent of the cost for operating costs, or about 20 per cent in all, the water company would reimburse him, without interest, for the amount he had invested. Meanwhile he would have added the additional cost to the price of the lots, just as he added the cost of the street improvements and sidewalks, and if the operation was undertaken with good judgment he would eventually get his money back. In this connection, it may be added that the chief engineer of the Indiana Public Service Commission recently stated that he believed extensions should only be required when the returns will pay for the improvement in five years.

STATE VERSUS LOCAL VIEWPOINT ON FILTER PLANT CONTROL[1]

By Robert B. Morse[2]

Within recent years the author has found himself in the peculiar position of having the responsibility both of supervising the operation of water purification works for the State and of operating such works for a sanitary district. During this period, the opportunity has arisen to study the contrasting mental attitudes which differences in function create in the same or different persons. Although the contrast between the viewpoints of operator and state employee is not as sharp as that indicated in the metamorphosis of a Jekyll to a Hyde, with either in the more desirable rôle, yet it is sufficiently interesting to make analysis valuable.

The duties of operator and state representative may be differentiated psychologically by remembering that in the first case emphasis is placed upon the means and the economy of producing a good water, while in the second the end product is all-important. The operator has placed upon him restrictions of time and money, under either private or municipal control, which automatically shift his major thoughts to methods and divert them from the ultimate product. The state representative, by the very nature of his duties, finds himself in a cosmos in which the final product stars, while costs and practicability sometimes take only non-speaking parts in the cast. The fact that the two men frequently stand on opposite sides of the fence may go far towards explaining some of the failures of state control to create real improvement in water supplies. An attempt will be made to indicate why in many instances the two do find themselves with a wall between them. With the reasons before us, a method of removing the barrier will soon appear.

[1]Read before the Cleveland Convention, June 8, 1921. Discussions are invited and should be sent to the Editor.

[2]Chief Engineer, Maryland State Department of Health, Baltimore; Chief Engineer, Washington Suburban Sanitary District, Washington.

Owing to the comparatively recent development of the scheme of water supply control by the state, it has come about that a large proportion of state representatives, particularly those in the field, are young men. Older men are not available in many instances because state budgets are still exceedingly lean. We then have before us, at the start, "youth" and its possible accompaniments, inexperience, lack of tact, impatience, and often self-importance, all qualities which, of course, older men are supposed to have eliminated or else to have learned to conceal.

When official governmental power is conferred upon maturity it sometimes leads to harmless pomposity; when it falls into the hands of youth it usually results in evident egotism, reinforced by a badge. This objectionable bureaucratic attitude is by no means uncommon in officials, whether municipal, state or federal. This sense of importance, based upon powers of statute, appears to be the cornerstone of the wall at one end, the state. The cement is furnished in abundance by youth.

On the other hand, is the operator the paragon of all virtues, preyed upon by the militant bearers of the law? Perhaps not. Whereas youth and power sometimes engender expansive chests, yet maturity and narrow experience may create the same psychical phenomenon at a more dangerous part of the anatomy, the head. The operator frequently meets the newcomer with an unfriendliness born of a resentment at interference of generally a younger man, who has had no particular and detailed knowledge of the operator's plant and just as often no special knowledge of plants in general. It is with this attitude of contempt that the other cornerstone of the wall is laid and, in this case, cement is no less plentiful, though supplied by experience.

It may appear, now, that we have reached this blank wall with suspicion and unfriendliness on one side, and force and egotism on the other, that the wall is insurmountable. It should not be. Any structure should collapse if its keystones are removed. In our present problem, the keystones are the result of attitudes and not of men. To destroy the keystones we need change only the viewpoint of the men. If the state representative, regardless of his lawful powers, will approach the plant operator in a spirit of helpfulness and with an open mind, if he will study carefully each plant before arriving at conclusions regarding improvements in construction and operation, if he will consult with, rather than rail at, the

plant operator in the realization that the good will of the latter is essential before any fruitful changes in control will be possible, if he will keep before him the desire to help and behind him the desire to order, then he will disintegrate his part of the barrier.

The task for the operator is a more difficult one, since it is that of converting suspicion into cooperation, where the fruits of cooperation are not at first apparent. The state official should find it easy to forget his badge, because by so doing the development of his plan becomes less arduous. The operator, however, has a greater difficulty in visualizing the benefits which accrue to him by accepting the offerings of the upstart. He feels that somehow he gives more than he receives, that he knows his own plant better than anyone else can, that his dignity suffers by permitting any interference or suggestion. If he may be brought to conceive, however, that youth may gather experience quickly through the continuous coördination of study of a number of purification works and may obtain an actual maturity of judgment through contact with varied problems at a series of plants, and that daily routine may have prevented him from keeping pace with developments in his field, then the operator may see the advantage of coöperation. Suspicion will almost always succumb to the helpful presentation of new ideas. Where views are continually changing and where new methods are appearing, the possibility of gaining knowledge of these through state assistance will do much to remove the antagonism of the operator.

It is apparent that the success of bringing operator and state representative together on common ground depends only upon the establishment of friendly relationship between them. In the case of the operator, it means the elimination of the feeling of resentment if aid is offered or criticism is necessary. That both of these may be desirable at some time is clear, since many operators are not all-wise, even if in practice for years. With the state representative, the establishment of an "entente cordiale" means practically the elimination of the superior attitude of governmental office. In both instances, much can be accomplished if each man remembers that the total of human knowledge is slight. It is wise to join in the use of each other's share, where, after all, there is so little to go around.

THE SMALL PLANT OPERATOR AS SCIENTIST[1]

By Abel Wolman[2]

To many small plant operators the title of this discussion may appear objectionable, for there still exists a vague distrust of the term "science." In most cases, a scientific worker or a scientific paper is synonymous with long words, difficult concepts, impractical ideas, and a certain aloofness of attitude. On the other hand, the so-called practical man stands with both feet on earth, talks American English, and presents facts that are workable and intelligible to the man who operates the pumps or fires the boiler. Is it not rather impertinent, therefore, to link these two conflicting spirits in the title chosen?

The author's task is to indicate that the absurdity of the contrast between "practical" and "scientific" is more apparent than real. This task has been chosen advisedly, since, by eliminating a certain amount of antagonism engendered by terms, it may be possible to bring about in the water works field a more fruitful use of the vast array of facts which the small plant operator has accumulated and will continue to collect.

Karl Pearson in the "Grammar of Science"[3] defines the function of science as "the classification of facts, the recognition of their sequence and relative significance." Stripped of its classical verbiage, the function of science is no more than the function of every technical practical operator, namely, the observation and interpretation of facts. It is important to emphasize that "a scientific frame of mind is not a peculiarity of the professional scientist."[3] And it is just as important to point out that, because scientific reports are often couched in English too elegant to be clear, it is not therefore true that science is a mere matter of language. It follows then that,

[1] Read before the Cleveland Convention, June 8, 1921. Discussions are invited and should be sent to the Editor.

[2] Division Engineer, Maryland State Department of Health, 16 West Saratoga Street, Baltimore, Md.; Editor, American Water Works Association.

[3] "The Grammar of Science," Karl Pearson; Part I, Physical; page 13. Adam and Charles Black, London, 1911.

if an operator sees facts and reasons as to their cause and effect, he becomes a scientific observer. The author is sorry to destroy, in this way, the illusion of some listeners that they, thank Heaven! are practical men and not theorists. He makes the charge that each man in this audience is a scientific worker, provided he is in possession of all his mental faculties. We must establish for ourselves, therefore, the axiom that practice and theory are not antithetical, but complementary.

A little thought will make clear that all plant operators may be divided into three classes, the first, who feel that they are scientific but hesitate to present their observations because of inherent modesty; the second, the practical, who observe but do not report because of a supposed lack of scientific language; and the third, who neither observe nor report. This last class is, it is hoped, numerically small and need not concern us. The first two classes have much in common, both as to method and result. It is to these two classes that one must look for real development in water treatment, since they are the first to encounter new problems and the first to try out new solutions. A scientific hypothesis is useless if it is not in accord with the facts everywhere. A scientific solution is worthless if it does not solve our problems. Both the hypothesis and the solution must be tested by the plant operator. He is an important factor in real scientific progress. How important, he has evidently failed to realize, if we judge from the infrequency with which he takes part in discussions of theory and hypothesis.

When we speak of a problem in water treatment, we are prone to emphasize its simplicity rather than its complexity. We find it easy to fall into the error of considering "water" as a definite thing, a simple compound, instead of regarding it always as a most variable substance, delicately fluctuating with atmospheric, geographic, and geologic influences. When water is considered in this sense, each water filtration plant becomes a laboratory, a scientific structure, a research bureau, where facts and opinions may and should be tested out upon the peculiar and rare fluid there being handled. When a new hypothesis is announced, each plant operator has the opportunity to make a real contribution to science and to practice by determining if it tallies with the phenomena experienced with his own rarity, the little stream used in his plant. Likewise, he has the continual advantage of learning whether older theories account for the present observations and whether older methods are adequate.

Each small plant stands, therefore, in the position of a special research laboratory, upon the director of which there has been placed the duty of watching and interpreting a continuous series of experiments performed under conditions common to no other laboratory. The author would emphasize the distinctiveness of each plant, since even on the same stream, a few miles apart, the water has undergone profound change which converts it into a new substance, with new, though possible slightly varied, attributes.

If we accept the concept of each plant as a true specialized investigative bureau and of water as a variable and not a constant substance, what operator has the right to say that he is not or should not be a scientific observer? His duty, whether he likes it or not, has been enlarged from that of valve-operator to investigator. His responsibility is greater than to his immediate community, it is national and even international. For the plant operator is now research worker, and the fruits of research are limited only by the infinite.

It is clear from the above discussion that in each plant, no matter how small, no matter how crude, phenomena of great importance and of peculiar significance are occurring and recurring. They are not always observed and still less often are they reported. It is the special plea of this paper to-day that this condition be remedied, for with its remedy, perhaps, many men, both scientists and practical men, will avoid voyages "bound nowhere, under full sail."

In concluding these remarks, the author has recourse once more to a quotation from the "Grammar of Science," which presents so much better than he can the argument for the reporting of facts and opinions by the small plant operator.

> It is as if individual workers in both Europe and American were bringing their stones to one great building and piling them on and cementing them together without regard to any general plan or to their individual neighbor's work; only where some one has placed a great corner stone is it regarded, and the building then rises on this firmer foundation more rapidly than at other points, till it reaches a height at which it is stopped for want of a side support. Yet this great structure, the proportions of which are beyond the ken of any individual man, possesses a symmetry and unity of its own, notwithstanding its haphazard mode of construction. This symmetry and unity lie in scientific method. The smallest group of facts, if properly classified and logically dealt with, will form a stone which has its proper place in the great building of knowledge, wholly independent of the individual workman who has shaped it. Even when two men work unwittingly at the same stone they will but modify and correct each other's angles.

THE LICENSING OF OPERATORS FOR WATER PURIFICATION PLANTS IN THE STATE OF NEW JERSEY[1]

By Charles H. Capen, Jr.[2]

The state of New Jersey has been one of the pioneer states in the work of water purification, largely on account of the necessity of providing extensive purification for surface waters taken from densely populated watersheds. The extreme case exists on one watershed where the average population is nearly 4000 persons per square mile.

With such conditions it has been necessary to require municipalities or companies to place in charge of their purification plants men who have had considerable experience and training in their work, or to educate the men in the essential principles of water treatment, allowing them to learn the details of their respective plants by experience. Formerly the latter method had to be relied upon entirely, but it later became customary for municipalities to cut down expenses by hiring unskilled labor, which resulted in the discharge of water unfit for potable purposes.

This led to the drawing up of a law which was passed on February 9, 1918, and which is known as Chapter 23 of the Pamphlet Laws of 1918 of the State of New Jersey, relative to the examination and licensing of operators, printed as an appendix to this paper. This act authorizes the State Department of Health to examine prospective operators and to issue a license, providing the examination of the applicant proves the latter to be capable of performing those duties which will be required of him. The nature, place and grading of the examinations are intrusted to the discretion of the Department.

It is further provided that every purification plant must have a licensed operator, but that licenses should be issued to all operators

[1] Presented at the Cleveland Convention, June 8, 1921. Discussions are invited and should be sent to the Editor.

[2] Assistant Sanitary Engineer, New Jersey State Department of Health, Trenton.

holding their positions prior to the time of the passage of the act upon proper certification by the municipal officer, corporation or individual, under whom the operator works. The Department is given the authority to revoke a license when, upon the operator being given a hearing he shall be judged incompetent to manage the plant in his charge, or shall have been wilfully negligent in his duty, or shall have disregarded or disobeyed the rules or regulations of the Department. There is provided a penalty of $10 for each day on which the violation occurs. It is further provided under the act that either before or after the institution of penal proceedings the Department may proceed to prohibit such violations by injunction, and to obtain such other or further relief as the Court may direct.

Following the passage of the act a set of rules and regulations was issued by the Department, outlining briefly the method of examination and grades of operators. An abstract of this follows:

> There shall be three classes of licenses issued to persons examined as superindendents or operators of water treatment works:
>
> A First Class, or Superintendent's, License shall be issued only to those persons having the qualifications and knowledge necessary for the satisfactory supervision of the operation of water treatment works, including the following processes: Sedimentation, coagulation, filtration, and disinfection; and for making the standard tests, both chemical and bacteriological, necessary for testing and controlling the efficiency of all the various processes used in water treatment works; and informed in general as to the mechanical equipment and devices used in water treatment works.
>
> A Second Class Operator's License shall be issued only to those persons having the qualifications and knowledge required in order to satisfactorily operate or control one or more of the processes required for a Superintendent's License; and having knowledge sufficient for the making of the routine standard tests, both chemical and bacteriological, for testing and controlling the efficiency of the various processes utilized in water treatment works which he expects to operate.
>
> A Third Class Operator's License shall be issued only to those persons having the qualifications and knowledge required in order to satisfactorily operate or control one or more of the processes not covered in the First Class License and the Second Class License. This class applies only to those operators having charge of a plant at which the removal of iron or disinfection is the only process of treatment.

As provided by this act there were 65 licenses issued without examination, and 14 licenses have been issued upon examination. These do not quite represent the total number of plants, as in a few cases it was necessary to issue more than one license.

In each case possible, representatives of the Department have spent from one to four days at the plant with the applicant for examination, and have drilled them in the routine fundamentals as well as in some of the more involved chemical and bacteriological tests. In other cases the applicants have come to the offices of the Department and have spent one or two days going over the operation of the plant from every standpoint possible without actually being at the plant in question. The principal points in each of several recognized standard books on water purification were also taken up. In some cases the applicant has been taken over to the Trenton filtration plant, and has been shown plant operation on a large scale. The results of showing operators a modern, well maintained and well operated plant have been noticable. In most cases both written and oral examinations have been given.

The benefits derived from this act are, of course, more or less intangible in aspect, but the greatest advantages seem to be in more personal interest in plant operation being taken by the operator (thus resulting in greater efficiency) and in the greater coöperation obtained between the operator and the Department. Frequently a municipality would in the past pay no attention to instructions issued as to changes in operation of a plant, but a licensed operator who is always at a plant knows the necessity of changes at times, and, realizing that his position may be at stake, will force the authorities to listen to his demands for changes or improvements. This is more often true of the men who have had to take examinations than of men to whom licenses were issued by virtue of their offices. This is partly due to the fact that those examined realize the responsibilities of their positions, while the others too frequently consider their position inviolable; and partly to the fact that the close contact of the applicants with the Department representatives creates a better understanding of the relations between operation by the applicant and supervision by the Department. Furthermore, the operator taking an examination has to study recent books on the subject and becomes acquainted with the latest developments. This studying does not end with the examination, as it has been found that men who prior to the examination did little or no reading whatever have now become subscribers to engineering and water works periodicals, and read them regularly with the beneficial results that always come with a wider scope of knowledge in a science that changes so rapidly. The desire for modern improve-

ments as a result of this type of reading is more common with the men examined than with the others.

These facts are not meant to indicate that the old operators are inefficient, as some of them are among the best in the country, but apply in general to the plants under 5,000,000 gallons daily capacity, where in many cases the salaries are too small to attract capable men.

At one filter that delivers 2,000,000 gallons daily capacity, running 24 hours, there were three men, each on an 8-hour shift, whose duties were to tend to alum and hypochlorite feeds, wash filters, fire the boilers, run a low-lift centrifugal and a high pressure reciprocating pump. The men were kept so busy that at times they were observed holding a sandwich in one hand while oiling the pumps with the other. If one were sick the others were forced to work 12 hours each. The plant was in a deplorable condition, and the water delivered was correspondingly poor (at that time complaints about the water were being made almost daily).

The Department threatened action unless a capable man was employed, and the town held up its hands in horror at the advice to pay at least $2000 a year to a capable supervisor. Finally a compromise was made whereby a consulting operator was employed to visit the plant at frequent intervals, and to make such recommendations and changes as seemed necessary. While even now the water is not always of the best, the complaints are not numerous and the efficiency of the plant increased so that the results now obtainable are limited only by the facilities, which can not be readily improved without rebuilding at least a large part of the plant.

In no case has the Department actually asked for the dismissal of an operator on the grounds of incompetency, negligence or disobeying the law, but several hearings have been held by the Department giving offending municipalities or companies an opportunity to show cause why conditions at the given plant should not be improved or changed in accordance with orders previously issued. In one case the matter of incompetency of a plant operator, together with the continued refusal of the company, was referred to the Attorney General for procedure in the Court of Chancery. Upon learning of this the company hired a new and competent operator and made changes previously advised by the Department.

The act was passed more than three years ago, but due to the large amount of preliminary work involved the full effect was not in substantial operation until the middle of 1919, giving the practical operation a fair test for about one and one-half years. The efficiency in applying the law has increased with time, the difficulties inherent in a new system having been gradually overcome. Some of the applicants at first appeared to resent some of the conditions imposed, including the taking of an examination, but most of this resentment has disappeared, and the results appear to be beneficial. It is believed that the standards will continue to improve, and while the act and its conditions are not perfect its provisions are so broad that the defects are mainly those of the application of the law to the individual cases.

In conclusion it may be said that the results of the act are as follows:

1. It tends to remove the positions of operators of water treatment plants from the influence of politics.

2. It improves the working conditions of the operators and results in their last recommendations for needed improvements receiving more consideration by their employers.

3. There is less friction between the water departments and water companies and Department of Health; the operators are gradually getting away from the idea that the representatives of the Department are trying to get something on them, and are beginning to place their problems before the Department inspectors for investigation.

4. It aids in securing a safe water for potable purposes from each purification plant.

APPENDIX

Chapter 23, Laws of 1918, New Jersey

An Act to provide for the examination and licensing of superintendents and operators in charge of water purification or treatment plants and sewage treatment plants under the direction of the Department of Health of the State of New Jersey.

Be it enacted *by the Senate and General Assembly of the State of New Jersey:*

1. In order that municipalities, corporations or individuals owning or operating water purification or sewage disposal plants may secure the services of capable superintendents or operators, the Department of Health of the State of New Jersey is hereby authorized to cause examinations to be made, by such persons and at such times and places as it may appoint and under

such rules and regulations as it may adopt, for the purpose of determining the qualifications of applicants for licenses as superintendents or operators in charge of any water purification or treatment plants purifying or treating water used for potable purposes by this State or of any sewage treatment plants discharging an effluent into any of the waters of this State. Every such examination shall be in such subjects and conducted in such a manner as the Department of Health of the State of New Jersey shall direct, and every applicant whose examination shall be approved by said department shall receive a license as superintendent or operator of public water treatment plants or public sewage treatment plants, as the case may be.

2. No municipality, corporation or individual shall appoint any person as superintendent or operator in charge of any water purification or treatment plant purifying or treating water used for potable purposes by inhabitants of this State or of any sewage treatment plant discharging an effluent into any of the waters of this State, or permit any person to discharge the duties of superintendent or operator in charge of such plant who is not the holder of a license issued by the Department of Health of the State of New Jersey under the provisions of this act; *provided, however,* that nothing herein contained shall prevent any municipality, corporation or individual from continuing in office any person now occupying the office of superintendent or operator in charge of any water purification or treatment plant or any sewage treatment plant, and the Department of Health of the State of New Jersey, upon certification from the proper municipal officer, corporation or individual, that such person held the office of superintendent or operator in charge of such water purification or sewage treatment plant at the time this act became effective, shall issue a license to said person in the same manner as if he had passed an examination held by the aforesaid department.

3. The Department of Health of the State of New Jersey may revoke the lincense of any superintendent or operator in charge of any water treatment or sewage treatment plant if, after a hearing held by said department at which said superintendent or operator shall have had an opportunity to be heard, either in person or by counsel, said department shall determine that the said superintendent or operator in charge is incompetent to manage said plant, or that he has wilfully neglected his duty in supervising the operation of said plant, or that he has disregarded or disobeyed the lawful orders, rules or regulations of said department.

4. Any person who shall violate any of the provisions of this act shall be liable to a penalty of ten dollars for each day on which such violation has occurred. All penalties prescribed by this section shall be recovered in an action of debt by and in the name of the Department of Health of the State of New Jersey as plaintiff.

5. All penalties collected under the provisions of this act shall be paid into the treasury of the State of New Jersey.

6. Whenever any municipality, corporation or individual shall violate any of the provisions of this act, it shall be lawful for the Department of Health of the State of New Jersey either before or after the institution of proceedings for the collection of the penalty imposed by this act for such violation, to file a bill in the Court of Chancery, in the name of the State, at the relation

of such department, for an injunction to restrain such violation and for such other or further relief in the premises as the Court of Chancery shall deem proper, but the filing of such bill, or any of the proceedings thereon, shall not relieve any party to such proceedings from the penalty or penalties prescribed by this act for such violation.

7. All acts and parts of acts inconsistent with the provisions of this act are hereby repealed.

8. This act shall take effect immediately.

Approved February 9, 1918.

WATER MAIN CLEANING IN KANSAS CITY, MISSOURI[1]

By Charles S. Foreman[2]

Water works engineers and superintendents usually know the necessity of cleaning certain water mains or feeder mains in the system which they may be operating, but before they are able to obtain authorization and appropriations to cover such work, they are called upon to answer many questions which may be brought up before a board of commissioners. The author believes that the publication of his experiences in water main cleaning in Kansas City during the past three years will be of value to other water works superintendents desirous of instituting similar work in the systems under their jurisdiction and that the following essential facts based upon his experiences will help to answer some of the questions which are usually asked.

1. The cleaning can be so arranged that a main need not be out of service longer than 12 hours for cleaning.
2. The cleaning process is not injurious to the mains.
3. An increase in carrying capacity of from 60 per cent to 85 per cent was obtained in large mains, and the carrying capacity of such mains was restored to that of new pipe.
4. The saving in coal costs alone, derived from cleaning, will pay the entire cost of cleaning within from 1 to 3 years.
5. The laying of additional mains to obtain increased capacity can be postponed until the consumption demands are equal to the maximum capacity of the old main on the basis of new pipe.
6. When taking as credits such items as coal saving and postponement of obligatory laying of new mains, the entire cost of cleaning is saved within from 6 months to 1 year.

In Kansas City, Missouri, for 2 or 3 years prior to the summer of 1918, there was always a lack of adequate pressure in the north and east portions of the city. This district is fed from the Turkey

[1] Presented at the Cleveland Convention, June 7, 1921. Discussion is invited and should be sent to the Editor.

[2] First Assistant Engineer, Water Department, Kansas City, Mo.

Creek pumping station through one 20-inch and one 30-inch cast iron water main. Laying additional feeder mains into these districts was abandoned because of the exceedingly high prices of material and the lack of funds. Therefore the proposition of increasing the carrying capacities of the old mains by the cleaning process was resorted to in the fall of 1918.

Tests were run on the 30-inch high pressure discharge line extending from Turkey Creek station to 17th and Baltimore Streets, a distance of approximately 6000 feet, for determining the interior condition and carrying capacity of this pipe, which was laid in 1886. The tests were made by making taps exactly 1000 feet apart upon a straight length of the main, there being no services or connections to the main between the gauging points. At each of these points 1-inch corporation cocks were installed for inserting pitometers and additional corporation cocks for pressure lines. A 2-inch pipe was connected to each of these taps, and 1000 feet of this pipe was laid along the surface of the ground, bringing the two together so that a U-tube could be connected in to measure the differential pressure between the two points. The 30-inch pipe was double traversed at each end pit and the average traverse coefficient obtained. A pitometer was then set at each pit for checking quantities flowing through the 30-inch main.

The scale on the differential U-tube was graduated in 0.01-foot divisions, and by using a liquid of specific gravity of 2.00 in this tube the readings obtained were in feet loss of head per thousand feet.

The advantages inherent in this method are that it is not necessary to obtain the difference in elevation between the two points, and that it eliminates the use of spring gauges. Piezometers could not be used because of the high pressure, all of the lines being under pressures of 125 to 150 pounds per square inch.

The pipe and connections for bringing the two pressures to the differential U-tube should be water-tight for accurate results. No difficulty was experienced in making them up tight. With pipe of $1\frac{1}{2}$ to 2 inches diameter, a slight leak did not materially effect the results.

The test extended over a 24-hour period so that both maximum and minimum velocities in the pipe could be obtained. The result of this test is shown graphically in figure 1.

It will be noted that the average pipe coefficient, as computed by the Williams and Hazen formula, was 69.69, this being lower than

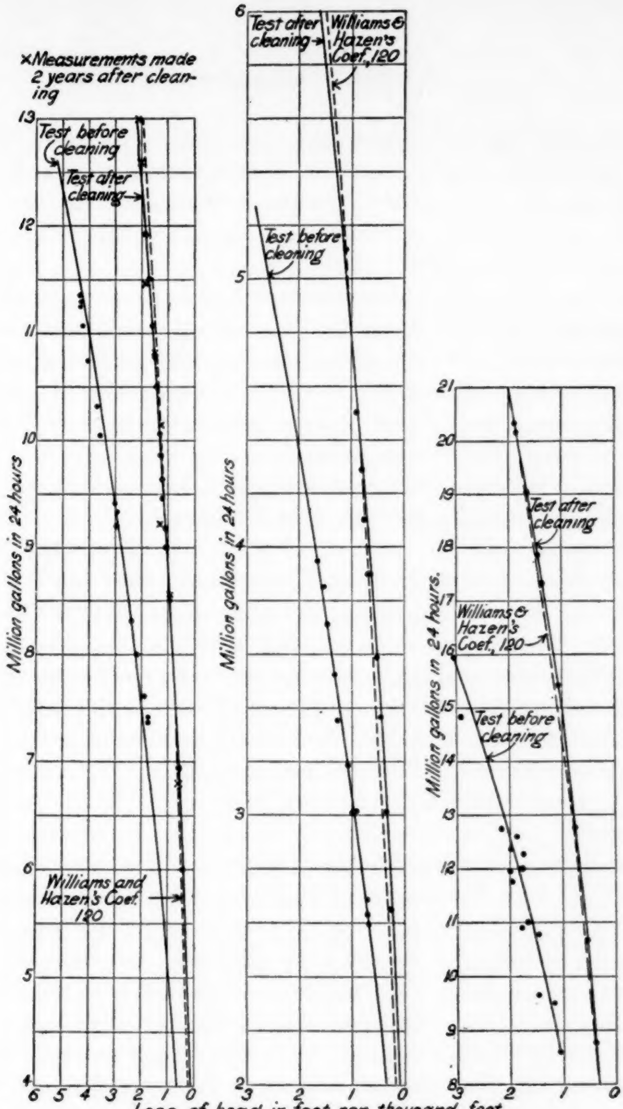

FIG. 1. TESTS OF 30-INCH HIGH PRESSURE MAIN
FIG. 2. TESTS OF 34-INCH HIGH PRESSURE MAIN
FIG. 3. TESTS OF 36-INCH FLOW LINE

	30 inch	34 inch	36 inch
Average diameter, after cleaning...	2.003	2.494	2.991
Area, before cleaning..............	3.1353	4.844	7.0266
Area, after cleaning................	3.151	4.885	7.0266
Ave. traverse coef., before cleaning	0.73	0.708	0.74005
Ave. traverse coef., after cleaning..	0.823	0.827	0.8584
Ave. pipe coef., before cleaning....	71.864	69.69	71.5
Ave. pipe coef., after cleaning.....	121.64	115.9	122.33

that in the Williams and Hazen tables for pipe 40 years old. From these tests it was evident that the 30-inch line was far below the carrying capacity of new cast iron pipe. A contract was awarded to the National Water Main Cleaning Company for the cleaning of 6000 feet of this 30-inch pipe.

Similar tests were run after the pipe had been cleaned and the results are also shown in figure 1. The average pipe coefficient was brought up to 116, and at low velocities, as high as 120, the carrying capacity of this pipe having been restored to nearly that of new pipe.

The cleaning of the 30-inch pipe gave such excellent results that a contract was let to the same company for the cleaning of additional feeder mains into the northeast section of the city, there being 30, 24, 20 and 16-inch pipe lines in this contract.

Similar tests were run on each of these pipe lines both before and after cleaning, and the results of some of them are shown in figure 2. In all of these cases, the pipe after being cleaned was restored to the carrying capacity and corresponding loss of head indicated in Williams and Hazen's tables under coefficient 120.

In making the test on the smaller lines, it was not practicable to place the gauging taps 1000 feet apart because of service connections and connections at street intersections. They were placed 200 feet, 250 feet and 500 feet apart, depending upon conditions encountered.

The liquid used in the differential U-tube was a mixture of carbon tetrachloride and bromoform brought to the required specific gravity by the addition of gasoline. The specific gravity was varied in accordance with the variation in distances between the taps on the line to be tested, so that in each case the readings on the U-tube were directly in feet loss of head per thousand feet.

In the spring of 1919, similar tests were made on the 36-inch flow line from the low-service station at Quindaro to the Kaw River tunnel, a distance of 17,000 feet. It was found that the average pipe coefficient as computed by the Williams and Hazen formula was 71.5 and that by cleaning this line the coefficient was restored to 122.33. See figure 3.

The methods used by the National Water Main Cleaning Company for cleaning large mains leave for the Water Department no intricate or expensive coöperative work. The section of pipe to be cleaned is valved off and a cut made at each end sufficient to admit entering and removing the cleaning machine. After cuts are made

and the machine inserted, the pipe is then sleeved up and the joints poured, after which the water is turned on behind the machine. After the machine once starts moving, it travels very rapidly through the main (3 to 4 feet per second), coming out at the open end of the section to be cleaned and bringing all the dirt and encrusting material out ahead of it.

The actual time any section of main is out of service depends almost entirely upon the speed which can be made in making the necessary cuts in the pipe and sleeving them up, as the actual traveling of the machine from one end to the other of a section of pipe requires but very little time. Usually the cuts on large mains can be so arranged that they can be made and repaired in approximately 12 hours, so that it is only necessary to have the main out of service for that length of time.

The actual cutting and repairing of the various mains was done by department forces, while all of the other work, such as excavating, backfilling, and placing of machine, was done by the contractor.

The contractor's price for cleaning ranged from 26 cents per foot for 16-inch pipe to 45 cents per foot for 36-inch pipe and the total cost, including all expenses for operating valves, cutting and repairing pipe and for all necessary sleeves and material, was $22,046.09 for 43,837 lineal feet of pipe cleaned, or 50.3 cents per lineal foot for all sizes.

The total cost of cleaning the various sizes, including pavement repairs and operation of valves, etc., was as follows:

7,202 feet of 16-inch pipe, $2,472.52 or 34.3 cents per lineal foot
7,280 feet of 20-inch pipe, $3,056.80 or 41.9 cents per lineal foot
3,371 feet of 24-inch pipe, $1,813.56 or 53.5 cents per lineal foot
8,984 feet of 30-inch pipe, $5,604.93 or 62.3 cents per lineal foot
17,000 feet of 36-inch pipe, $9,098.28 or 53.5 cents per lineal foot

Referring again to figure 1 the average flow through the 30-inch pipe from Turkey Creek Station to 17th and Baltimore Streets before cleaning was 11,100,000 gallons per day and the friction loss was 4.23 feet per thousand feet. After being cleaned, with the same quantity of water passing through the pipe, there was a friction loss of 1.6 feet per thousand feet or a net gain of 2.63 feet per thousand feet, amounting to 15.78 feet for a total of 6000 feet cleaned. This was also checked approximately with pressure gauges at each end of the line and is equivalent to a saving of 1,460,000,000 foot-pounds of work per 24 hours.

Had this been a line through which it was desired to deliver 11,100,000 gallons of water per day at a certain head, there would have been an actual saving in coal of $6.67 per day or $2,435 per year, so that the saving in 1 year of coal alone almost equals the cost of cleaning.

However, as a constant station pressure of 150 pounds is carried at Kansas City, the cleaning resulted, either in increasing the pressure in the downtown district 15.78 feet with the same quantity of water passing through the line, or with the same loss of head as before cleaning, the quantity delivered through the line would be approximately 19,500,000 gallons per 24 hours, or an increase in carrying capacity of 8,400,000 gallons per day or nearly 80 per cent.

To obtain the same increase in capacity as the cleaning of the 30-inch pipe resulted in, would mean the laying of an additional 24-inch feeder main. The estimated cost of such a line at that time was $88,800 and the annual interest on this amount at 5 per cent is $4440, making a total annual saving of $6944 as against a total total cost for cleaning of $3720.50.

In the case of high pressure distributing mains, the cleaning of the 26,000 feet of various sized pipe now permits the delivery to the northeast section of town of approximately 12,000,000 gallons per day more water than before cleaning without increased head at the pumping station. Therefore it will be readily seen that the laying of additional feeder mains can be postponed for some time by keeping the present feeder mains up to their maximum carrying capacity.

In the case of the 36-inch flow line, it was found on the test before cleaning that with a loss of 2.7 feet per thousand feet the line was flowing 16,000,000 gallons per 24 hours. This was practically the maximum amount of water that it was possible to put through this line with the limiting head of 50 feet on the Quindaro pumps. The test after cleaning indicated that with the same loss of head, the capacity had been increased to approximately 26,000,000 gallons or 75 per cent.

In other words, this gave the department an increase in flow-line capacity of approximately 10,000,000 gallons per day, which was greatly needed during the periods of maximum consumption in the summer of 1919. Under normal conditions of consumption, the cleansing of this flow line actually resulted in a saving of 1.7 feet of friction loss per thousand feet.

Table 1 shows the length of time in service, the annual operating cost for coal, before and after cleaning of the various sizes cleaned. Also the investment required and the annual interest thereon to obtain the increased capacity by laying new mains and the total annual saving, all being based on 5000 feet of each size and on the normal flow through the pipe at time tests were made.

Inspection of the interior of the mains after cleaning discloses that the machine had no injurious effect upon the interior surface.

TABLE 1

Annual costs and saving before and after cleaning on basis of 5,000 feet of each sized pipe

SERVICE YEARS	SIZE	M. G. D. NORMAL FLOW	LOSS OF HEAD PER 5000 FT.		ANNUAL COAL COST TO OPERATE LINE		ANNUAL COAL SAVING	SIZE REQUIRED TO OBTAIN INCREASE IN CAPACITY IF NOT CLEANED	ESTIMATED COST 5000 FT.	INTEREST ON EXPENDITURE 5%	TOTAL ANNUAL SAVING	TOTAL COST OF CLEANING.
			Uncleaned	Cleaned	Uncleaned	Cleaned						
	ins.							*ins.*				
41	16	2.4	24.00	7.50	$462.53	$144.53	$318.00	12	$27,200	$1360	$1778.00	$1715
42	20	3.4	23.50	5.60	641.60	152.89	488.71	16	33,100	1655	2143.71	2095
28	24	5.0	12.60	5.25	505.90	210.79	295.11	16	33,100	1655	1950.11	2675
33	30	12.0	23.50	9.00	2264.46	867.24	1397.22	24	70,000	3500	4897.22	3115
33	36	16.0	15.25	6.00	3740.52	1471.68	2268.84	30	73,500*	3675	5943.84	2675

Annual cost for fuel to pump one million gallons one foot high at Quindaro = $0.042.

Annual cost for fuel to pump one million gallons one foot high at Turkey Creek = $0.022.

* No pavement or rock.

Surface supply, Missouri River water.

The springs on the machine are not set stiffly enough to cut into the cast iron and in many instances where inspection was made, it was found that the old tar coating was still in the grains of the iron. The machine in many instances was sent around sharp curves, some as sharp as 60-degree bends, and also through open gate valves, without injurious effect. It cleans the walls of the pipe very thoroughly and leaves it practically as smooth as new pipe.

As to the question of how long the benefits derived from the cleaning of water mains may be expected to last, the author has heard

it stated many times that after a pipe had once been cleaned the corrosive effect or the formation of tubercles was very much more rapid than before cleaning. In fact, the contractor stated that the carrying capacity might decrease the first year but would be less rapid thereafter. With a view to ascertaining what this effect would be on the 30-inch main, permanent pitometer pits were put in so that tests could be run from time to time after the cleaning. Accordingly pitometer and loss of head tests were run again in the fall of 1920 on this main and the results of these tests are also shown graphically by the crosses in figure 1. It will be noted that two years after cleaning, there was practically no change in results from the test run immediately after the pipe was cleaned. This would indicate that the corrosive action is no faster after cleaning than on ordinary new pipe.

The author believes that in designing and laying new feeder mains, serious consideration should be given to the advisability of building permanent pits with removable sections of flanged pipe so that a main can be readily and cheaply cleaned from time to time.

It is now the common practice among engineers, when computing the size of pipe required to deliver a certain quantity of water, to use the loss of head figures given in Williams and Hazens tables under coefficient 100, thus providing a larger size than necessary under coefficient 120. It can be readily seen that the interest on the saving in first cost between the smaller and larger pipe will far more than pay the cost of maintaining the smaller pipe at its maximum capacity by cleaning it whenever necessary.

THE WATER SUPPLY OF MEMPHIS, TENNESSEE[1]

By J. N. Chester and D. E. Davis[2]

The water supply of Memphis, Tennessee, has been intermittently prominent in engineering discussions for forty years, because of the many unusual and interesting features connected with securing the water from the artesian sands. The artesian supply was first discovered in 1886 through the drilling of a well by a local industry. Shortly afterward the Water Company abandoned the plant on Wolf River, immediately above the city, which furnished untreated water, and in 1890 it put into operation the Auction Avenue artesian plant, which is still in service.

The City purchased the property of the Artesian Water Company in 1903 and shortly thereafter began to extend its search for water into other districts. In 1906 it erected a temporary air lift plant in South Memphis, some 5 miles distant, and in 1908 the Central Avenue air lift plant in the east end of the city and about 3½ miles from the Auction Avenue plant, was completed and is still in daily operation. Beginning in 1910 the Water Department supplemented its supply by sinking individual wells at points on the system where the pressure required reinforcing. These wells were equipped with vertical-shaft deep-well pumps actuated by electrical motors and delivered the water directly into the mains, thus incorporating both low-lift and booster service in the same unit.

At the present time, the plant supplies a population of about 180,000 which requires a little over 13,000,000 gallons of water daily, or 72 gallons per capita. One reason for this low per capita consumption is that about the same total quantity of water is taken from the water-bearing stratum by industrial and commercial plants. The combined fire and normal consumption demands upon the municipal works today call for a plant able to supply water at the rate of 32,000,000 gallons daily, whereas the existing facilities of the water

[1] Read before the Central States Section, September 28, 1920. Discussions are requested and should be sent to the Editor.

[2] Of The J. N. Chester Engineers, Union Bank Building, Pittsburgh, Pa.

department can furnish water at a rate of less than 24,000,000 gallons daily, the fluctuations in load being largely taken up by the individual motor-operated pumps scattered over the system. This situation led the water commissioners to retain the authors' firm to make an investigation of the conditions, and this paper will outline some of the interesting features of this unusual water works system which the investigation revealed.

Source of supply. All the water is obtained from an aquifer, or water-bearing stratum, of sand. This is reached at depths below the surface ranging from 340 to 575 feet and is overlaid and underlaid by clay strata. This artesian sand outcrops in a belt about 40 miles wide, lying parallel with the Mississippi and about 22 miles eastward from the city at its nearest point.

Quality of supply. The bacterial quality of the water is very good. Chemically, it is marked by considerable carbonic acid gas, which causes some red-water troubles. The solids in solution form soft scale, but there is no difficulty with hard scale. The character of underground waters from scattered wells is so likely to show marked variations that a chemical survey of the public and private wells throughout the city was made. As soon as a supply was taken from a well it was tested for free carbonic acid gas, and later duplicate samples were tested for iron and alkalinity. The results of this investigation showed that the water decreased in hardness as the distance eastward from the river increased. This steady decrease was not so marked in the case of the iron and carbon dioxide, but it held true in a general way. The iron content ranged from a trace to 3 p.p.m. The water obtained in the East End district is in every way better than the water nearer the river. This result, so far as carbon dioxide content is concerned, cannot be attributed to the air pumping in the East End because the electrically pumped wells display similar characteristics. Since there is a relationship between hardness of water and the distance of wells from the river, there might be a presumption that the river itself might be responsible for the result. This is quite improbable because the head under which the wells operate is greater than the elevation of the river, except, possibly, during the highest floods, thus preventing a backflow, and the river water is much softer than the ground water.

The artesian water contains from about 1.50 to 10 p.p.m. of dissolved oxygen, the quantity being higher in the supply pumped by the air lift than in the rest. Tap water from buildings with

wrought iron or steel pipes was without any dissolved oxygen but the iron content was much higher, 14 to 20 p.p.m., than that in the water as it came from the wells, indicating the corrosive action of the carbon dioxide. This corrosive action has long been recognized in the city, so that the majority of premises have house plumbing and service lines entirely of lead. There was also a great increase in the alkalinity of the water before it was drawn from these taps. The water from many of the wells near the river gave off a distinct odor of hydrogen sulphide, but this was not detected in samples from wells in the eastern part of the city.

Future consumption. The future growth in the population of Memphis has been estimated by comparing its growth with that of a number of other cities with similar characteristics, from which it appears that an average growth of 5000 per year may be reasonably expected. Based upon a corresponding increased demand on the plant and taking into account the fire protection requirements as laid down by the National Board of Fire Underwriters, the average and maximum demands in gallons per day which the plant should be prepared to meet are,

	Average	*Maximum*
1920	13,200,000	31,800,000
1930	14,900,000	36,400,000
1940	20,000,000	46,000,000

Available supply. One of the critical questions in this study has to do with the decision as to whether or not it will be safe to further exploit this artesian supply, therefore, several methods of approach to the solution of the problem have been employed. The ultimate source of the ground water is, of course, that portion of the rainfall over the sand outcrop which finally percolates into the sand. The average annual rainfall where the artesian sand outcrops east of the city is about 48½ inches. An examination of the local conditions and records indicates that a conservative estimate of the proportion of the rainfall which percolates through the sand to Memphis is 15 per cent or 350,000 gallons per square mile of outcrop area, per day. As there are at least 320 square miles of this area which may safely be considered as the source of the supply for the city, it seems reasonable to count on an average daily available supply of over 100,000,000 gallons. This might be pictured as a slow-moving stream which would yield this amount without depleting the source.

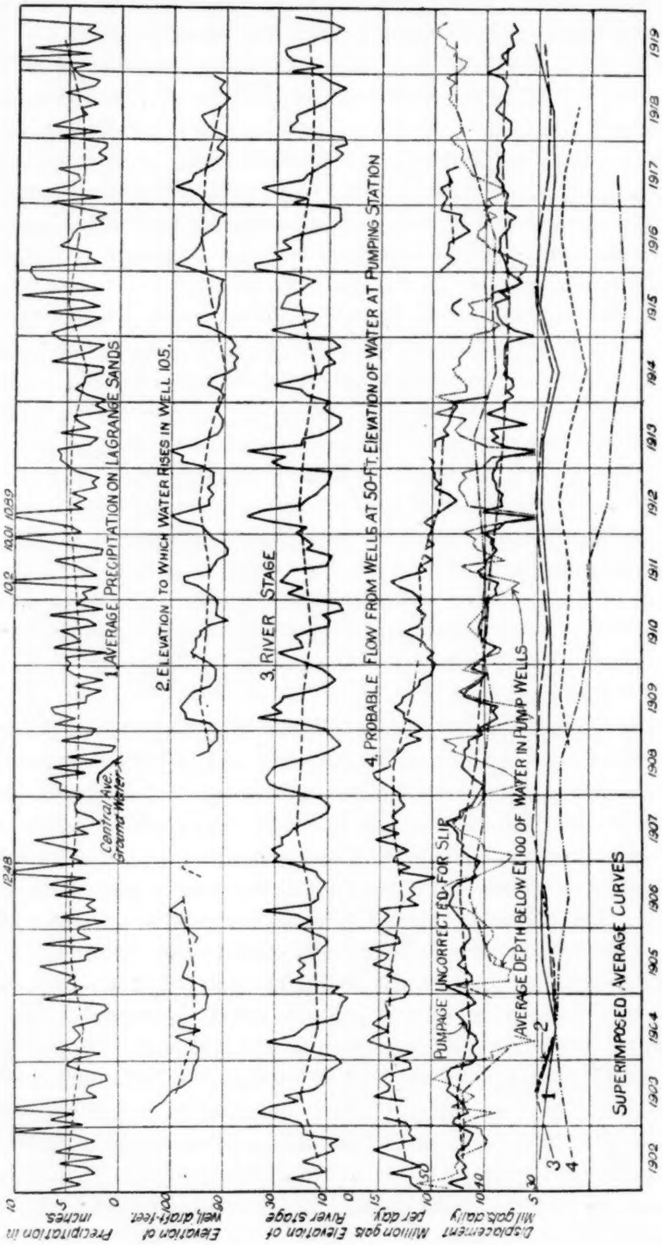

FIG. 1. MONTHLY AND YEARLY CURVES OF PRECIPITATION, RIVER STAGE AND WELL CONDITIONS

A second fruitful approach to the problem lies in the study of well records (some of which extend over a period of 30 years), to discover the effect of continuous draft on the water level of the artesian aquifer. The relationship between the rainfall, river level, and artesian water elevation together with other variables is shown in figure 1. These curves will be found of considerable interest and their study early developed the fact that comparisons of water elevations were of little value unless the seasonal variation in elevation was discounted. The variation between the high point in the spring to the low point in the fall has been as great as 11 feet, while the average annual variation appears to occupy a range of about 7 feet. There is also established a relationship between the elevation of the water in the river with the artesian water level, as well as between it and the rate of rainfall, which latter shows a lag in its effect upon the artesian plane, as might be expected.

No definite outlet can be established where the underground sands give up their water to the river, but the evidence leads to a strong presumption that some such connection actually exists. If this is so, then of course any rise in the river would tend to back up the water in the underground sands until a sufficient head was created as to force the underground water into the stream. This variation is of considerable significance in a practical way since, when coupled with the knowledge that the quantity of water derived from a well varies directly with the head on the well, this seasonal change affects to a marked degree the water which can be secured from the sands. The pumps at Auction Avenue are fixed as to elevation and the water cannot be drawn down in the pump well below a certain point. It is quite evident, then, that a 7 foot or greater difference in the head on the wells will make some difference in the quantity derived when the water in the well is lowered to the same elevation. A study of the relations between pumpage at Auction Avenue and the corresponding artesian water elevation during one period indicated that for an average difference of 9.4 feet in head on the wells there was a corresponding difference of 1,900,000 gallons per day as derived from the wells. At another period, for a head difference of 6 feet, the effect on the well delivery was 1,100,000 gallons per day. These results represent an average of 15 per cent of the available capacity at a given time.

The effect on the individual centrifugal pump wells cannot be studied in the same manner, but from the form of the characteristic

and efficiency curves, it is known that a change in head does result in changed delivery conditions. In air-lift wells the effect of changed head on the wells is likewise marked, but since these changes do make a difference in the submergences of the wells and consequently the delivery under similar conditions of pumpage, it may be safely concluded that the quantity of water derived from these wells is also affected. A study of records from the air lift station at Central Avenue does, in fact, tend to substantiate the conclusions, for during one period when there was a variation of 11.6 feet observed in the head on the wells, there was a corresponding difference of approximately 500,000 gallons per day as derived from the wells during the two periods or about 12 per cent of the available water. For another period an observed drop in head of 4.1 feet resulted in a decrease of 270,000 gallons per day in the pumpage.

After sufficiently accounting for this seasonal effect of variations in artesian water level, the study of several sets of data seems to warrant the general conclusion that the drop in general water level from the time when the sands were first drawn upon to the present time is not in excess of 16 feet and probably not less than 5 feet. Stated in another way, the drop in water level per million gallons of water drawn from the sands by all wells (municipal and private) is probably not more than 0.3 foot, and considering the incomplete nature of the data involved, a working basis of 0.5 foot per million gallons will serve as an extremely conservative estimate, including something for a factor of safety.

Some further light on the available water supply results from the observation of the speed with which the water level in the wells resumes its initial undisturbed elevation after pumping has stopped. It is to be understood that when wells are pumped there is a drop in elevation of the water in and around the well and when pumping is stopped the water gradually approaches its former undisturbed level. It may be shown that the recovery at Auction Avenue was practically complete in five hours, of which 75 per cent was attained in one hour, while for the Central Avenue district, where the sand conditions are better, the corresponding figures are 1 hour and 20 minutes respectively. A well in the extreme south end of the city, which is affected by the pumping in the city and whose head was lowered 5 feet during the day, showed complete recovery during the night.

The study of all these data seems to warrant the conclusion that this artesian aquifer can be developed to at least three times its present yield before the economic limit of pumping is reached.

Life history of Memphis wells. One of the most interesting developments in connection with this whole investigation has been the derivation of the age characteristics and life history of the wells. Fortunately accurate monthly records of the flow of many of the wells have been available. Some of these records extend over a period of 30 years. In figure 2, the history of the yield of wells in the Auction Avenue District, drilled in different years, is shown graphically. Each curve represents the mathematical average yield of a group of wells drilled during a given year. In order to determine the ageing of the wells, each series has been plotted by showing the yield for each year of its age, plotted on the same base. The resulting average curve is quite instructive and indicates that there is a very definite limit to the life of every well drilled in this locality. The yield of every well drops off rapidly during the first five years of its history and more gradually during its later life, this in spite of the fact that the wells are given periodic attention in the way of flushing and cleaning, the results of which are reflected in the curves. The data from which these curves were drawn were taken from the meter records of each well, as measured and recorded monthly, since 1902, by the resident engineer, and are believed to accurately represent true conditions obtaining over the period.

The life history of the Central Avenue wells is of the same general character (see figure 3), although their initial yields, and consequently their yield on each succeeding year, is much higher than the average in the other district, and the ageing effect similar. The similar ageing of the wells leads naturally to a discussion of the causes for this decrease in yield in these wells, and the explanation lies at hand that the clogging of the strainers by the fine sand, by corrosion and incrustation, and by the deposit of iron oxide and possibly other solids, notably lignite, are some of the contributing factors leading towards this result. There are also indications that the sand in the vicinity of the strainers becomes permeated with accumulated material, such as finer sand and principally iron oxide or ferric hydroxide, so that ultimately the opportunity for ingress of artesian water into the wells becomes exceedingly limited. This is recognized as a practical consideration, since the Water Department has maintained a well crew for the purpose of periodically cleaning these wells

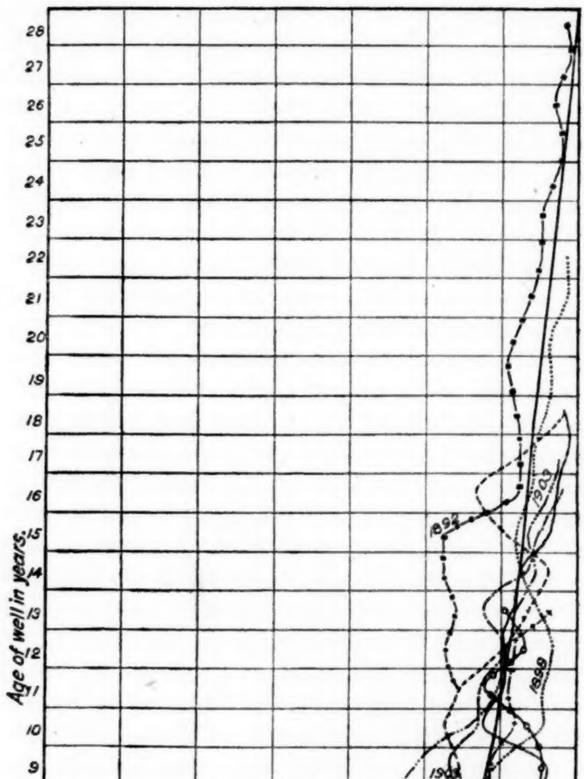

FIG. 2. AVERAGE LIFE OF WELLS IN AUCTION AVENUE DISTRICT

by different methods of washing, viz., removing the strainer, cleaning it, and restoring it into the well; and telescoping a worn-out well by sinking a pipe of smaller diameter within the original casing to a point below the original level and placing another strainer at this new sand stratum.

The effectiveness of various methods employed in improving the flow from wells which have fallen off in yield may be seen by consulting table 1, made up to show the average increase per well as derived from a series of observations extending over a period of years. It is quite evident then that in order to maintain the supply at a uniform rate, it becomes necessary to drill a certain number of wells each year. It is estimated that in order to maintain the Auc-

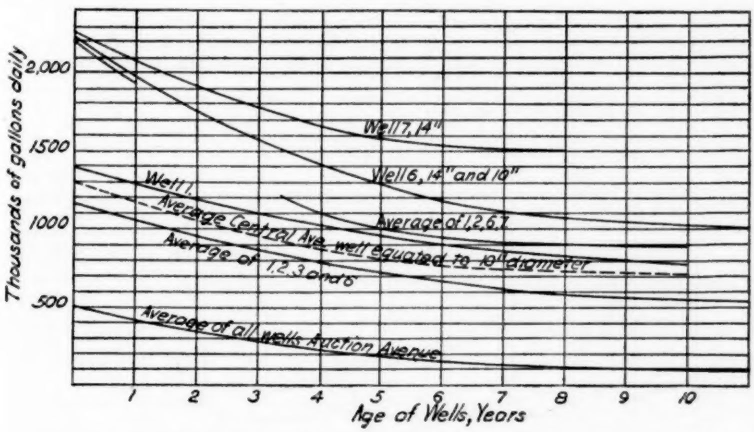

FIG. 3. LIFE AND YIELD OF WELLS FROM TEST DATA

tion Avenue yield at 10,000,000 gallons per day, it is necessary to drill five new wells per year.

In order to compare the yields of wells in the two districts, the conditions were reduced to a similar base and all wells compared on a 10-inch diameter. The resulting curves are shown in figure 4, where the calculated yields for 10-inch wells are shown and the observed yields of 12- and 14-inch wells. In searching for the reason for the marked difference in well yields in the two districts, the influence of well diameters, strainer lengths, and sand analyses were studied. Fortunately samples of sand from many of the wells had been saved and rather definite conclusions as to its effect are therefore warranted. To summarize the whole subject of well yields, the following conclusions are set down in brief form:

TABLE 1

Average increase in flow of wells after cleaning in various ways

YEAR OF DRILLING	OPEN FLUSH			TOOL FLUSH			OVERHAUL			TELESCOPE		
	Before*	In-crease	Per cent	Before*	In-crease	Per cent	Before*	In-crease	Per cent	Before*	In-crease	Per cent
1892	78,161	68,000	87.0	113,000	76,000	69	79,000	94,000	117	93,000	344,000	370
1898	140,000	21,000	15.0	104,000	106,000	102	67,000	134,000	200	35,000	253,000	720
1900	117,143	41,000	35.0	107,000	115,000	108	65,000	132,000	203	88,000	361,000	410
1902	147,000	25,000	17.0	140,000	69,000	49	80,000	154,000	193	102,000	150,000	150
1903	200,000	22,000	11.0	122,000	65,000	53	119,000	162,000	135	41,000	540,000	1300
1904	180,000	9,000	5.0	132,000	121,000	92	133,000	165,000	124			
1906	126,000	34,000	27.0	143,000	122,000	85	106,000	188,000	177	68,000	327,000	480
1907	103,400	60,000	58.0	111,000	110,000	100	148,000	130,000	88	49,700	318,000	640
1913				105,000	105,000							
Total....	1,091,704	280,000		1,077,000	784,000		797,000	1,159,000		476,700	2,293,000	
Average.	136,463	35,000	25.6	119,666	87,111	72.8	99,625	145,000	145	68,100	328,000	482

* Flow in gallons per day before renewing well.

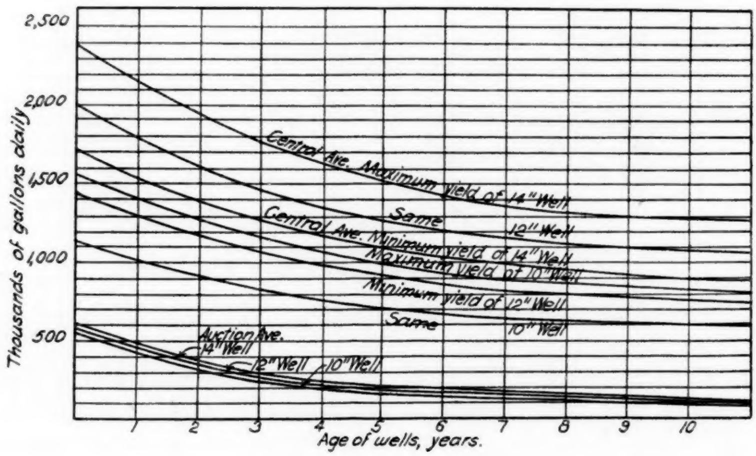

FIG. 4. EXPECTED LIFE AND YIELD OF WELLS

Expected yields are based on a 40-foot drop between the ground water elevation some distance from the well and the elevation of water in the well. The yields given above are 45 per cent of the yield of a well when pumped alone, or an allowance of 55 per cent for interference.

1. That all wells drilled into this sand drop off in yield with advance in years according to a rather definite law.

2. That there is a very rapid drop off in yield in the Auction Avenue wells within the first two years and that the rate of decrease in yield after that date is more gradual.

3. That for the average well at Auction Avenue, the initial yield when first drilled is about 570,000 gallons per day, which decreases to approximately 100,000 gallons per day at the end of ten years, corresponding to yields of 1,300,000 and 700,000 respectively for similar wells at Central Avenue under this same consideration.

4. That the wells at Central Avenue show from two times (for 10-inch wells) to four times (for 14-inch wells) greater yield than do wells in the Auction Avenue District.

5. That the probable explanations for the decreasing yield of wells are:

a. The clogging of the strainers by fine sand.

b. The corrosion and incrustation of the strainer.

c. The deposit of iron oxide and possibly other solids, notably lignite, in the strainer openings and in the surrounding sand.

6. That in order to maintain a supply at a constant level, it becomes necessary to sink new wells periodically.

7. That an increase in the diameter of a well affects the yield according to strainer and casing friction.

8. That the effective size of the sand has a very appreciable effect on the yield, that is, the larger the sand, the greater the yield, and that yields vary as the square of the ratios of the effective sizes of sand.

9. That the effective size of sands in the East End District is much greater than in the Auction Avenue District.

10. That two or three times as much water may be anticipated under the same conditions from the East End as from Auction Avenue for a 10-inch well; two and one-half to three and one-half times for 12-inch; and three to four times for 14-inch, consequently the East End District offers much better opportunities for exploitation than the Auction Avenue District.

Attention is especially directed to statements (7) and (8) as indicating the paramount importance of the size of sand grain upon the yield of the wells, also as showing that in wells of large yield, where friction loss is a factor, the wells of large diameter are a good investment when measured in terms of yield.

Interference of wells. There was an opportunity at the Central Avenue Station to make a detailed study of the mutual interference of the wells and the effect of their spacing upon this interference. The capacity of each when the others were shut down was first determined. Then these wells were pumped in pairs and the mutual interference of each well in a pair was found to result in a loss of capacity per well ranging from 3 per cent in one pair to 25 per cent

in another. The wells were next pumped in various groups of three, when the interference was found to reduce the capacity per well from 14 to 26 per cent. Finally, the wells were pumped in groups of four, and the loss of capacity per well under such operating conditions was 28 to 34 per cent. These data are only applicable to the local conditions at this station at the time of the tests. For instance, the minimum loss of 3 per cent mentioned above was due largely to the fact that one of the wells was new and of large capacity.

The effect of the spacing on the interference is well shown by the complete data, but the details need not be given here except for one example to show the close agreement of theory with observed results. This is the case of three wells. No. 7 is at one end of the base of a triangle, the base being 515 feet long. It yields 1,700,000 gallons daily when the other wells are not pumped. No. 8 is at the other end of this base and yields 2,060,000 gallons when it alone is pumped. No. 1, is at the apex of the triangle, 350 feet from No. 7 and 225 feet from No. 8. When well 8 is pumped and the others are not pumped, the water table at that well drops to 11.1 feet below its normal elevation, and the water table at well 7 is pulled down 2.65 feet. When only well 7 is pumped, the water table there is pulled down 8.7 feet and at well 8 it drops 2.1 feet. Since the yield of these wells has been found to vary directly with the drop in the water table, after allowing for friction losses, the theoretical yields are easily computed. When well 7 alone is pumped, it causes a drop in the artesian water table at well 8, so that at the latter the available head to cause water to percolate into that well is only 11.1–2.1 or 9 feet. When both wells are pumped simultaneously, the yield of well 8 will be reduced from the yield when it alone is pumped by an amount proportional to the reduced head. The theoretical yield will therefore be $9/11.1 \times 2{,}060{,}000$ gallons, or 1,670,000 gallons. In the same way the theoretical yield of well 7, with both wells 7 and 8 pumped, can be found to be 1,180,000 gallons. Under such conditions the two wells will theoretically yield 2,850,000 gallons; the field tests gave a combined yield of the two under such conditions of 2,950,000 gallons. The effect of pumping at these two wells on well 1 was carefully checked by observing the drop in the artesian water table there, and the theoretically determined elevations agreed within a few inches with the observed elevations. The rise in the head may be conceived as being uniform in all directions when a single well is being pumped, giving the appearance,

therefore, of an inverted cone to the artesian water head curve. When more than one well is operating these cones intersect, thereby cutting off the flow available to each. The interference becomes more pronounced, the more wells there may be located in a given vicinity. The interference would probably be lessened where the wells are placed in a single line. The theoretical relationship between rise in elevation with distances from the well for a 12-inch well flowing 2,000,000 gallons and with friction and other loss of 4 feet shows that the interference will be roughly as given in Table 2.

TABLE 2

Effect of spacing of wells at Central Avenue on their mutual interference when pumped in pairs

Distance between wells in feet	10	50	100	200	300	500	1,000	3,000	4,000
Percentage of interference	67	48	41	32	29	23	18	6	0

In determining the best spacing of wells, other factors than their interference must be considered, such as the cost of connecting them with the water mains, the cost of equipping them with pumping apparatus, and the cost of pumping, including the effect of friction losses on that cost.

Auction Avenue pumping station. This station was built in 1890 and its present condition, after thirty years' service, offers an opportunity for an interesting study of the depreciation and obsolescence of a high-grade plant of the date of its construction. The buildings are in excellent condition, and the same is true of the two 135 by 5½-foot stacks. The latter are amply able to furnish draft for any requirements which are likely to arise here; each stack has a capacity of 750 horse power under the operating conditions that are probable.

After thirty years' service the six Heine water-tube boilers set in two batteries are still in use, which speaks well for the care given to them. They furnish steam at very low pressure, 100 pounds being their rated maximum, and they are small according to present practice and without superheaters and other features now considered desirable in stations of this general character. Tests of three of them gave an evaporation of 7.59 pounds of water per pound of coal, from and at 210°, into steam at 85.6 pounds pressure. These are good results for the coal and such boilers. The criticism of the plant is that it is obsolete to a considerable degree.

The three vertical, compound, high-duty Worthington pumps were erected in 1899 and their steam ends entirely renewed about ten years ago. They are set in a dry well, 38 feet in diameter and 47½ feet deep. They are in good general condition, but their slip was found to be 15.7, 17.4 and 23.4 per cent, the smallest slip being in a pump in which new plungers were fitted in 1919. Their test duty when erected was over 105,000,000 foot-pounds per 100 pounds

TABLE 3

Operating cost comparisons showing average annual costs and costs per million gallons pumped from January 1, 1914, to January 1, 1919

	AUCTION AVENUE		CENTRAL AVENUE		SEGREGATED WELLS		AVERAGE	
	Average annual	Per million gallons	Average annual	Per million gallons	Average annual	Per million gallons	Average annual	Per million gallons
Salaries	$14,048	$5.52	$11,754	$12.18	$2,610	$5.65	$28,412	$7.16
Fuel	18,532	7.28	19,373	20.08	19,527	42.30	57,432	14.48
Oil and waste	2,140	0.84	1,341	1.91				
Repairs to plant	3,376	1.32	1,314	1.36	1,214	2.63	10,618	2.68
Miscellaneous	66	0.03	667	0.69				
Total	$38,162	$14.99	$34,949	$36.22	$23,351	$50.58	$96,462	$24.32
Well maintenance	8,411	3.31	120†	0.12	300†	0.65	8,831	2.22
Tunnels, etc. maintenance	807	0.32					807	0.32
Total	$47,380	$18.62	$35,069	$36.34	$23,651	$51.23	$106,100	$26.76
Pumps, special maintenance*	3,742	1.47					3,742	1.47
Wells, special maintenance	28,809	11.31	600†	0.62			29,409	7.41
Total	$79,931	$31.40	$35,669	$36.96	$23,651	$51.23	$139,251	$35.11
Interest, (calculated)	34,000	13.36	7,040	7.31	4,600	9.98	45,640	11.50
Depreciation, (calculated)	12,750	5.01	4,400	4.56	2,300	4.99	19,450	4.90
Total	$126,681	$49.77	$47,109	$48.83	$30,551	$66.20	$204,341	$51.51
Gallons per day (corrected)	6,980,000		2,642,000		1,262,000		10,884,000	

* Proportion of whole amount.
† Estimate.

of coal, whereas the plant has averaged only 27,500,000 to 40,200,000 foot-pounds since 1908. This low duty is due to a number of conditions, such as inability to operate any unit at its full capcity for more than a short period, the condition of the auxiliaries, and the necessity of keeping ready for fire service over 100 per cent of the capacity needed for normal service. The operating requirements make it difficult to keep the pumps in the best running condition. The auxiliary equipment should be replaced in large part.

Auction Avenue well system. The method of developing the ground water supply at Auction Avenue has long been a subject of unusual engineering interest, and the condition of the wells and collecting system today deserves rather detailed description, for there is little printed information concerning it. When the station was built, it will be recalled, the present methods of obtaining water from large wells were either unknown or not of demonstrated reliability. Hence only the artesian head of the water in the aquifer was utilized to deliver the supply to the pumping station.

From the bottom of the dry well at the pumping station a shaft 10 feet in diameter was sunk to a depth of 80 feet below the surface. The shaft was sealed at the top and around the pump suction mains where they enter it. At the bottom, the shaft has been connected with a brick-lined tunnel, which has been extended from year to year until it is now somewhat over a mile long. From this tunnel numerous timber-lined drifts have been driven, having a total length of over five miles. Access to the tunnel and drifts is had through a number of shafts. The drifts run to or by the wells, which are connected to them in such a way that the well water flows freely into them. There are 70 of these wells in service now, most of them 10 inches in diameter.

On two occasions this supply has been seriously polluted. In 1912, a flood caused by high water in the Mississippi broke into one of the shafts, which is believed to have been damaged previously, at the time some pavements were laid. In 1919, a sewer settlement, due to some unknown cause, resulted in the flow of sewage down the outside of a well casing and through the timber lining of a drift into the artesian water. Deplorable consequences attended this last case of contamination.

These major cases of pollution and several minor cases led the author to make a critical examination of the relative locations of wells and sewers and it was found that there were 44 wells within 10 feet of sewers, measured horizontally. He has accordingly advised encasing the sewer with reinforced concrete or replacing it with cast iron pipe for a distance on each side of the well. This recommendation is based not only on the inherent possibility of leakage from the average sewer, but also on the conditions caused by the sinking of some of the wells. The loosening of the earth about the well casing, particularly when the well is sunk rapidly, may afford such an opportunity for very free percolation of water

and even for the running of fine sand containing much water in its pores, that the earth supporting a neighboring sewer may be disturbed in the course of time, causing the sewer to crack and leak. There have been 23 instances of surface subsidence caused by the washing of materials into drifts, due to a breaking of the connection between a well and drift. This breaking can be attributed only to the loosening of the material about the well casing to such a degree that the resulting pressure of the material above the connection finally becomes great enough to cause its failure.

The condition under which the Auction Avenue Station's supply is obtained, the great difficulty of shutting off one or more drifts from the tunnel in case polluted water is flowing through them, and the present condition of the tunnel and drifts, coupled with the fact that wells in this part of the city yield much less water than those farther east, determined the author to advise discontinuing further extensions of this plant. It is his opinion that all wells at this location should be discontinued as soon as an adequate supply can be obtained elsewhere.

Central Avenue pumping station. This station was built in 1907–1908, apparently without much expectation that it would become a permanent plant. The engine room was well laid out, but the boiler room is so cramped that there is insufficient room to tend fires, handle coal and ashes, and renew boiler tubes.

Steam is furnished by five 5 by 18-foot return tubular boilers rated at 150 horse power each, but unable to meet this rating because each has only a 60 by 2½-foot steel guyed stack to furnish draft, which such a stack cannot supply properly. Tests of three boilers showed thay were evaporating 6.93 pounds of water, from and at 210°, into steam at 113.2 pounds pressure, per 100 pounds of coal. There are adequate facilities for coal storage, but the conditions make the handling of coal and ashes very expensive.

The six wells directly connected to this station are pumped by air lift. The station has five cross-compound,condensing, two stage compressors, each rated at 500 cubic feet of free air per minute at its maximum permissible speed of 120 r.p.m. All of them exhaust into a surface condenser with 1000 square feet of cooling surface, the condensing water coming from and returning to the receiving basin into which the well water is discharged. The compressors and condenser are in fair condition, and two of the compressers gave a duty when tested by the author in pumping a large yield well of 22,500,000 foot-pounds per 1000 pounds of steam.

The high service pumping is done by five compound condensing simplex pumps. Each is rated at 1,000,000 gallons and has a separate surface condenser, which may, however, be connected to any or all pumps. On test, three of these pumps showed a duty of 26,400,000 foot-pounds per 1000 pounds of steam.

The average annual duty of the whole station during the last ten years has been from 10,300,000 to 13,200,000 foot-pounds per 100 pounds of coal.

Central Avenue wells. It has already been stated that the relatively coarse sand of the artesian stratum near this station yields freely a water which contains less iron and carbonic acid gas, is lower in alkalinity and causes less clogging of the strainers and the sand about them than the water at the Auction Avenue station. When the station was built, the choice of the air lift for pumping the wells was a wise one. Three 10-inch wells yield from 800,000 to 900,000 gallons each when the artesian water table is lowered 17 feet and another such well, 2200 feet from the station, yields 1,000,000 gallons when the water table is drawn down 35 feet. There is a 14-inch well which gives 1,600,000 gallons with a lowering of 18 feet in the water table, and a 12-inch well yielding 2,060,000 gallons with 16 feet lowering of the water table. The decrease in yield of the wells with their age has already been mentioned. The water is delivered into a well-built covered receiving basin 32 feet in diameter and about 25 feet deep.

Independent well pumps. For many years the use of independent or segregated pumps at Memphis has been of special interest to water works engineers. As long ago as 1903, the late T. T. Johnston, consulting engineer of the water department, was interested in developing such pumps and a considerable investment was made in them under his direction down to 1908. In the following year a type of pump devised by W. J. Wills, then general superintendent of the department, was developed and its installation in some of the wells was begun in 1910. At present there are 14 of these pumps installed. They have an electrically driven vertical shaft with a screw pump at its bottom, which lifts water to the suction of a centrifugal pump having its runner at the top of the same vertical shaft.

Tests of three of these equipments showed an efficiency of 30.6 to 43.5 per cent. The bottom pump has a much lower efficiency than the centrifugal pump at the top, and where this bottom pump

has much work to do, the efficiency of the complete unit is less than the efficiency when the bottom pump carries a smaller proportion of the total load.

In a general way, the author's investigations at Memphis convince him that the work done with independent pumps there has made a substantial contribution to deep well pumping practice, and that there will be a field in that city for independent well pumps until marked additions are made to the art of deep well pumping as now conducted. Certain rules should be observed in installing such units, however, in order to take full advantage of all the experience gained with them down to date.

The wells should not be sunk on streets or alleys where the presence of sewers introduces dangerous conditions and it is necessary to place the pumps in pits difficult to drain and affording little space for maintenance and repairs. The pumps should be above ground, in a building of good appearance, with a roof, part of which can be removed to enable the shaft to be lifted out be means of a derrick and tackle. Each pump should have an air separator and an automatic recording Venturi meter on its discharge pipe, with gate and check valves. There should be a recording watt-hour meter in each pump house, so that records of the input and output of the pump will give immediate warning of any falling off of efficiency.

Expenses. Memphis has had a sufficiently long experience with each of its three methods of deep-well pumping to permit comparisons of cost to be made between the systems over a period of years and under the conditions of operating there existing. The figures in table 3 those taken from the operating records of the Water Department, which is operated as a self supporting concern and practically as though it were a private company. In explanation of the term "special maintenance," it will be recalled that in order to maintain the supply of water from the wells intact, it becomes necessary to drill new wells at regular intervals. The cost of such items of renewal are charged to this special account. The cost of overhauling and rebuilding pumps was spread over several years, as it appeared unfair to penalize any one year with this expenditure. The fixed charges are not the actual amounts paid, but are based on certain percentages applying upon the investment in the plant as carried on the books of the Water Department.

Improvements. The purpose of this paper is to report the condition of the Memphis works, as the author found them. These works have been discussed a great deal in engineering circles, but comparatively little has been published concerning them of late years, and very little has been ever printed concerning them considering the interest they aroused for something like twenty years. From what has been said, it is readily seen that parts of the plant are outgrown and parts present objectionable features in the light of our present knowledge of public sanitation, and in closing the author will indicate briefly his recommendations for their improvement. The greatest need is storage of water, to equalize the work of the low-service pumps and give an opportunity to rid the water of its iron and dissolved gases, as well as to afford a suitable place for chlorination. Attempts to chlorinate the water at the Auction Avenue station have not been satisfactory because of operating conditions. It is possible to build a 10,000,000 gallon reservoir near that station which will accomplish the purposes named, and in addition furnish an adequate storage supply for fire protection near the part of the city where the need for it is greatest.

The Auction Avenue station is a well built structure and located so favorably for serving some of the most important parts of the city that the heavy investment there should be utilized so far as practicable and economical. Fortunately this can be done by remodeling the plant and developing gradually a new system of wells free from the objections to those now in use. So far as these new wells are concerned, they can be sunk on a line connecting this station with the Central Avenue station and thus be able to supply either station, and the two stations can be so equipped that there will be duplicate apparatus for pumping the wells, installed at different points, however, which is highly desirable. Not the least among the advantages to be secured through extending the line towards the East End district is the opportunity it affords of reaching the coarser sand and better water of that district.

The low-service pumping capacity at the Auction Avenue station can be improved and increased by converting one of the Worthington pumps into a triple-expansion engine by replacing its steam end. This can be used in delivering water from the present collecting tunnel to the new storage reservoir. The other Worthington pumps can be kept as they are for service in the present fashion, so long as the collecting tunnel is used. Two 10,000,000-gallon pumps

should be installed for direct pumping from the storage reservoir into the distribution system and a modern boiler plant is a necessity.

The Central Avenue station, located at a point where the city owns a large plot of land, should have a 5,000,000-gallon storage reservoir. In order to place this station on a good operating basis, there should be installed three batteries of water tube boilers with superheaters, a new stack, a 5,000,000-gallon high-duty pump, a new Corliss air compressor and coal handling equipment. The extension of the well system supplying this station can be readily carried on as needed.

The independent wells, discharging into the distribution mains, can apparently be pumped most advantageously by electrically driven segregated pumps, generally speaking, but wells located along the collecting mains discharging by gravity to the pumping stations can apparently be pumped most advantageously by the air lift. These are general statements based on local Memphis conditions, and the author makes them with the distinct reservation that even at Memphis the best equipment of each well should be considered as an independent engineering problem.

Like most distribution systems, that at Memphis needs extensions and reinforcement at places. The meters need overhauling and more attention should be given to waste prevention and the continuous supervision of the quality of the water.

HYDROGEN ION CONCENTRATION AND ITS APPLICATION TO WATER PURIFICATION[1]

By R. E. Greenfield[2]

It is quite probable that most of those present are wondering just what hydrogen ion concentration is and why ,whatever it is, it should appear on this program. It probably suggests some of the mysteries with which chemists from the time of alchemists to date have been popularly supposed to occupy themselves.

The purpose of this paper is to attempt to tell what the hydrogen ion concentration is and why it is of interest to waterworks men. Most of them have some idea what is meant when one speaks of an alkaline solution and an acid solution. All know that the things called acids usually have a sour taste, and what are called alkalies have a soapy taste. All know, also, that there are certain colored compounds, such as litmus and methyl orange, which have one color in an acid solution and another in an alkaline solution. As will later be shown, different indicators do not give the same result in many acids. Some of those present may have heard the excellent paper on this subject given by Dr. Washburn before this society in 1910.

Hydrochloric acid, or as it is commercially called, muriatic acid, is made up of hydrogen and chlorine, HCl; nitric acid is HNO_3, sulphuric acid, H_2SO_4; acetic acid, HAc, the Ac being a short abbreviation for a complex radical made up of carbon, hydrogen and oxygen; and boric acid, H_2BO_2 often called boracic acid. The only thing common to them all is hydrogen, and it is natural to conclude, therefore, that the properties persons normally think of in an acid must be due to the hydrogen. Now consider the chemical formulas for certain of the better known alkalies, $NaOH$, KOH, $Ca(OH)_2$, etc. The common constituent is the OH radical made up of oxygen and hydrogen, and it is to this radical that the characteristic basic properties must be attributed. The OH and H, if taken together, make up the elements of water.

[1] Read before the Illinois Section, March 23, 1921. Discussions are invited and should be sent to the Editor.

[2] State Water Survey, Urbana, Ill.

While all acids have certain properties in common they do not always have these properties to the same degree or intensity. Take solutions of three acids, equal volumes of each solution containing equivalent amounts of acid. The first is hydrochloric or muriatic acid; most of those present know that this acid, even in quite dilute solutions, say 3 per cent, has an extremely sour taste, in fact it will quite severely burn the tongue and even the tougher skin of the hand. The second acid solution is acetic, the acid found in vinegar; ordinary vinegar is about 3 to 4 per cent acetic acid and everyone knows that it is only pleasantly sour, hardly burning the tongue at all. If one were so rash to as place some in his eye he would suffer some inconvenience. Those here may never have tried this, but some may have had sour orange juice spattered in his eyes and that is about the same as vinegar. The third solution is boric or boracic acid. This, in from a 3 to 4 per cent solution, is a popular eye wash, causing no discomfort when dropped in the eye and does not have a sour taste at all. These three solutions, in addition to affecting the senses differently, also do not affect all indicators in the same manner. Just as the sense of taste and feeling vary with the intensity of the acid reaction, indicators are also of different sensitivity. For instance, thymol blue, which is red in acid solutions and yellow in alkaline solutions, is not very sensitive, being only affected in the strongest acids. If a small portion of the indicator is added to each of the three acid solutions already mentioned, the hydrochloric acid turns the indicator red but that the other two make it yellow. To this indicator, therefore, the acetic and boric acids are alkaline. Another indicator, bromphenol blue, is yellow in acid solution and blue in alkaline. It is somewhat more sensitive to acids. Adding it to the three acid solutions, the hydrochloric and acetic acids react acid, but the boric does not. A third indicator, bromthymol blue, which is very sensitive to all acids, is also yellow in acid solutions and blue in alkaline. Adding it to the three acid solutions, each gives an acid reaction to this indicator. A little of this third indicator added to a solution of sodium hydroxide, which is strongly alkaline, will turn it blue. This is sufficient to show that while one may take equivalent amounts of different acids there is a certain difference in the intensity of the acid properties.

It has been found by a large number of experiments that any acid, when put into solution in water, tends to break apart into the hydrogen ion and other ions of which it is composed. In the case

of hydrochloric acid, hydrogen ions and chloride ions would be produced. Acetic acid gives hydrogen ions and acetate ions, the latter being rather complex radicals which chemists abbreviate into Ac. Boric acid gives hydrogen ions and borate ions. This splitting up into ions is called "ionization." Now it has also been proved that not all acids ionize to the same extent. For example, in the hydrochloric acid solution the hydrochloric acid ionizes about 90 per cent, but the acetic acid only ionizes about 2 per cent, and the boric acid ionizes only very slightly indeed, about 0.005 per cent. An acid which ionizes greatly is called a strong acid, and it will have the very sour taste, ability to smart and burn the skin and give an acid color to all indicators, like hydrochloric acid. Those that do not ionize to such a great extent are called weak acids and the above mentioned properties vary in intensity according to the amount of ionization.

From this reasoning, it will be seen, therefore, that the sour taste and ability to change indicators depend not upon the total amount of acid per unit volume but upon the total amount of ionized hydrogen per unit volume. And that is what the hydrogen ion concentration is, the total amount of ionized hydrogen per unit volume of the solution under consideration. Alkalies ionize in a similar manner, as do all salts. The properties of the alkalies depend upon the extent of the ionization in a way similar to the acids.

In most natural water carbon dioxide or carbonic acid is present in solution. This is a very weak acid like the boric acid, but it is an acid and gives a definite hydrogen ion concentration. This hydrogen ion concentration has recently attracted much attention. Biologists have found that the small plants and animals growing in water are much affected by changes in it. Some organisms are unable to exist in certain streams because of too high or too low hydrogen ion concentration. For this reason considerable interest is attached to the determination of the hydrogen ion concentration of surface waters. One way of making this determination is by means of indicators. An indicator is selected which changes color at about the hydrogen ion concentration that the water is thought to be. A small portion is placed in a solution of known hydrogen ion concentration, an equal amount is placed in a sample of the water being examined and the colors are compared. If the color is the same, the hydrogen ion concentration of the water is the same as that of the known solution; if the colors are different, known solutions with different hydrogen ion concentration are tried until a match is obtained. Making compari-

sons in this way and having at hand a selection of indicators and a set of solutions of known compositions the hydrogen ion concentrations of which vary in a progressive manner, it is practicable to make these determinations quite accurately. There are other and, for some purposes, better methods of making these determinations but there will not be time to go into them here.

The hydrogen ion concentration also has a great deal to do with whether or not water will corrode metals. It is possible to illustrate this in a rather gross manner with the same acids which were previously selected as types. If a piece of zinc is dropped into the hydrochloric acid, which has a high hydrogen ion concentration, a good deal of gas rises, indicating that the metal is dissolving or corroding rapidly. If zinc is dropped in the acetic acid, which has a lower hydrogen ion concentration, there is also an evolution of gas but not nearly so much. The boric acid solution, which has a very low hydrogen ion concentration, has no apparent effect on the zinc. It has long been known that free carbon dioxide or carbonic acid in water would cause the water to be corrosive; the experiments just mentioned show that the corrosive effect is to a considerable extent due to the hydrogen ion concentration built up by the carbonic acid. Two waters containing the same amount of free carbonic acid do not necessarily have the same hydrogen ion concentration and do not, therefore, have the same corrosive action. The hydrogen ion concentration produced by an acid varies inversely with the concentration of the other ion with which the hydrogen is associated in the acid. A water that contains 10 parts per million of carbonic acid will have a much higher hydrogen ion concentration and be, therefore, more corrosive than one containing the same amount of carbonic acid and say 200 parts per million of carbonates, for the carbonates, such as calcium and magnesium carbonates, also ionize to give carbonate ions and calcium or magnesium ions. This increase of carbonate ions serves to decrease the hydrogen ion concentration. This effect, which is called the common ion effect, can be illustrated by means of acetic acid. Into a tube containing acetic acid and an indicator which the acetic acid caused to show its acid color, add a small amount of sodium acetate, a salt of acetic acid and there results a great increase in the concentration of the acetate ions. There is also an almost immediate change of color of the indicator, showing that there has been a decided decrease in the hydrogen ion concentration. Therefore a study of the hydrogen ion concentration of natural waters

may serve to throw some light upon the probable effect of the waters upon metals. The same information cannot be obtained by simply determining the total amount of carbonic acid which the waters contain.

The third point of interest is the precipitation of the alum in the coagulation of water preliminary to sedimentation and filtration. The hydrogen ion concentration is of importance, since if the water is too acid or, as more commonly stated, deficient in alkalinity, the alum will be precipitated incompletely or not at all, making the use of lime necessary. Since this precipitation of aluminum depends upon the hydrogen ion concentration of the water, the proper control of the hydrogen ion concentration would be all that is necessary to obtain satisfactory coagulation results. It does not seem too much to hope that very soon automatic machines will be developed which will be controlled by the hydrogen ion concentration of the treated water and which will regulate the dosage of alum and lime that is to be added to the water.

The precipitation of calcium and magnesium in a water softening reaction is very similar to the alum coagulation and it would seem that in this case, the controlling of the softening plants by means of the hydrogen ion concentration might not be too much of a chemist's dream.

The State Water Survey Division is at present engaged in studying the last three reactions with a view to determining the changes in hydrogen ion concentration which take place throughout the progress of the reactions, with the hope that accurate information on this point will be of value in working out better methods of control.

Summary. To summarize, the hydrogen ion concentration of a water or for that matter of any solution is a measure of the extent to which the various acids and acidic compounds in the water are ionized or broken up into hydrogen ions and acid radicals. It is what might be termed the intensity factor of acidity as opposed to the quantity factor which is obtained by measuring the total acid or alkali found in the solution. The hydrogen ion concentration of water is of interest to water-works men, first because it is one of the factors controlling the life of animal and vegetable organisms in the water; second, because it is one of the factors in corrosion; and, third, because the study of this hydrogen ion concentration offers a possible improved means of controlling the coagulation and water-softening reactions used in water purifications.

GLIMPSES AT THE PAST AND FUTURE OF THE CHICAGO WATER SUPPLY[1]

By John Ericson[2]

This is an informal talk made at the request of the new city engineer of Chicago, Alexander Murdock, and is based on the information gathered and opinions formed during a connection of about 37 years with the water works of the city. So much has been written and said about the subject that it is difficult to tell anything new, but an attempt will be made to show how the experience of the past throws light on the problems of the future.

When the author first entered the city's service in 1884 the area of the city was 37 square miles and its population was 601,000. There were two pumping stations, the Chicago Avenue Station and the so-called West Side Station on Ashland avenue near 22nd Street. Each station had old-style vertical beam engines, the oldest one, "Old Sally" at Chicago Avenue, having been installed in 1853, and the newest ones, the pumps at the West Side Station, in 1876. Some additional beam engines were placed in this station in 1884. The nominal capacity of the Chicago Avenue Station was 56,000,000 gallons, and of the West Station 30,000,000 gallons per day. There were two tunnels, 5 feet and 7 feet in diameter, supplying these stations from a crib located at that time two miles from shore. The distribution system consisted of 520 miles of cast iron mains, interspersed with some remnants of old bored logs.

Today the population of the City is 2,800,000 and its area about 200 square miles. There are ten large stations with a combined nominal capacity of 1,170,000,000 gallons per day and more additions are under way. There are about 64 miles of water tunnels supplying these stations from six intake cribs, and the water is distributed through 2940 miles of mains. From the old beam engines the pumping machinery has developed into high-grade triple-expansion engines

[1] Read before the Illinois Section, March 23, 1921. Discussion is invited and should be sent to the Editor.

[2] Consulting engineer, 30 North La Salle St., Chicago, Ill.

and turbine and motor- driven centrifugal pumps. There are now 52 pumping engines in the system.

The development in the design of intake cribs has also shown a steady progress, from the early wooden structures with their great buoyancy and expensive protecting breakwaters, to structures built of steel, concrete and stone throughout, the new Wilson Avenue crib being an example.

When the first 5-foot lake tunnel, proposed by Mr. Chesbrough in the early 60's, was up for consideration, many engineers and builders declared the project impractical. The tunnel was built, however, and was at that time considered a great feat of engineering. Since that time there has been a gradual increase in the size of the intake tunnels. When the Four Mile Tunnel off 12th street was designed in later 80's, the size was increased to 8 feet, and a contract awarded the for its construction. After the tunnel had been constructed lakeward for some distance, the contractor apparently got "cold feet" and succeeded in convincing the city authorities that to continue the construction as an 8-foot tunnel under the lake was impracticable, and thus obtained permission to substitute two parallel 6-foot tunnels in place of the 8-foot tunnel. Incidentally, this also increased the cost of this improvement by over $100,000.

When, in 1895, the author was requested to design a lake tunnel to supply the proposed Springfield Avenue and Central Park Avenue pumping stations on the West Side, it was, after due investigation, deemed practicable and advisable to make this tunnel 10 feet in diameter. Even then there were determined efforts made to change the design. After the contract had been let and the tunnel pushed lakeward about a thousand feet, the contractor and others left no stone unturned to have the plans changed so as to permit the construction of two parallel 8-foot tunnels in place of the 10-foot tunnel. Those who were familiar with the situation at that time will remember the stubborn fight which had to be made to prevent this change. The tunnel was afterwards constructed as a 10-foot tunnel without any serious difficulties whatever and in a perfectly straight line from the shaft at the foot of Oak street to the Carter H. Harrison Crib.

As still larger tunnels were afterwards deemed desirable, a further and special investigation was made regarding this subject, and in projecting the 14-foot lake tunnel in 1907 from the foot of 73rd street to the Dunne Crib it was decided to go deep enough to bring the bore of the tunnel into solid rock. The Wilson Avenue tunnel,

12 and 13 feet in diameter, completed in 1918 by day labor, is also constructed through solid rock; likewise, the new Western Avenue tunnel system, now under construction.

Where large tunnels are required and suitable rock is exceptionally deep, the problem will again have to be given special consideration. Sometimes, years after the tunnels have been built, those responsible for the work have been criticized because the tunnels were not made larger. The unforeseen growth of the city, both by annexations and actual increase in population, has greatly increased the demand for water above what could be reasonably anticipated when the earlier tunnels were planned, and the limitations as regards the art of lake tunnel construction when those tunnels were built should answer such criticisms. There are other reasons that will be touched upon later.

One of the drawbacks in the development of the water supply system of Chicago has been the constantly increasing abnormal demands upon the system, the per capita pumpage having been at times among the highest in the world. This average per capita pumpage has been steadily increasing year by year until in 1920 it amounted to 265 gallons, without satisfying all demands.

Twenty years ago in making an investigation as to what becomes of the water pumped for city uses, the author came to the conclusion that a great percentage of the water is lost through unwarranted waste and leakage. A campaign for the reduction of this great waste was then inaugurated, and has been kept up intermittently ever since, with more or less discouraging results. The optimistic view taken of the prospect of remedying this situation in the earlier part of this campaign may have had its effect in not pushing new additions to the system as hard as if the great opposition to water meters and other restrictive measures had been anticipated.

The campaign, however, led to systematic water surveys and the organization in 1907 of a permanent engineering corps in the distribution or so-called Water Pipe Extension Division of the Bureau of Engineering. The valuable work done and being done by this small corps of engineers is known and appreciated by but few. Through their efforts it is now possible to pierce through the soil with our mental eyes, discover the weak links in the system, and trace the thousands of streams of water that disappear without doing any useful service. In planning for the future, from time to time, this work has been of inestimable value, and since the last study for future require-

ments was inaugurated in 1916, the work was developed to a point so that there is now a complete record showing the use and abuse of the water supply, and an intelligent estimate of future requirements of water in every square mile of the city can be made.

In the early days, before the construction of the Chicago Drainage Canal, the quality of the water supply was very bad. On a survey made for the Chicago Drainage and Water Supply Commission in 1887, after a rather protracted rainfall, the author personally traced the field of highly polluted Chicago River water for over two miles out into the lake, where it extended beyond and surrounded the only intake crib at that time. The death rate in those days from typhoid fever amounted to as high as 173 per 100,000 inhabitants. The opening of the Drainage Canal greatly relieved this situation, but, as the city continued to grow by leaps and bounds, there were and still are periods when the typhoid death rate shows an increase and when the people are warned to boil their drinking water.

In 1912 the first experimental hypochlorite of lime installation was made at one of the intake cribs, but it was operated under more or less severe difficulties. A second installation more carefully constructed was later installed at another crib, but still with unsatisfactory results. A year or two later, sufficient experiments had been made with liquid chlorine to warrant such installations at some of the pumping stations. These installations have gradually been extended and improved until the deaths from typhoid during the past few years have dwindled to around 1 per 100,000. The question now is: Will this solve the sanitary question as regards our water supply for the future? H. O. Garman, chief engineer of the Indiana Public Service Commission, recently read a paper before the Indiana Sanitary and Water Supply Association, in which he said:

> Few committees appreciate that it is but one step from home to the cemetery and that our place in a home or in a cemetery is absolutely in the hands of some obscure, unknown, underpaid, and too often unappreciated employee of the purification department of our water utilities. The management and operation of a water utility is almost a sacred occupation.

This about expresses the author's view when some eight or ten years ago, he recommended that an expert sanitary engineer be employed to look into the future sanitary requirements of the Chicago water supply which recommendation however was not acted upon.

The government requirements for potable water supplies have been

gradually brought to a high standard. Will Chicago be able to meet them without finally having to resort to filtration? If not, a tremendous problem confronts the city.

With a pumpage today of an average of 265 gallons per capita or over, or 730,000,000 gallons per day, and with the population growing at the rate of 60,000 per year, the filtering of this quantity of water will be a Herculean task.

When, in addition, the sewage treatment question is taken into consideration, is it not time that much more determined efforts be made to eliminate the abnormal waste and leakage in the water supply system and bring the per capita pumpage to a reasonable quantity? These are questions that should receive the earnest attention not only of the City's officials and engineers but of every public-spirited citizen and the engineering organizations.

IMPOUNDED WATER AT BLOOMINGTON, INDIANA[1]

By D. H. Maxwell[2]

Bloomington is located on the summit of the divide between the east and west forks of White River in the driftless area of southern Indiana. A ground water supply is not available. The topography is rugged and good reservoir sites for an impounded supply are apparently plentiful on the contour map. Unfortunately the impounded supply that has actually been developed by the city has been unsatisfactory and inefficient. To appreciate one of the serious defects in the existing impounded supply, and the possibility of a satisfactory reservoir supply, it is necessary to consider the geological structure in this vicinity.

Geological structure. The rock formations at Bloomington are stratified and dip gently to the west southwest, so that the successive outcrops form north and south strips from $\frac{1}{4}$ mile to 4 miles wide, their lines of contact made very irregular by surface erosion. The lowest formation exposed in the vicinity of Bloomington is the Knobstone, consisting of dense sandstones and shales several hundred feet in thickness which appear in the bottoms and sides of the valleys to the north, east and southeast of the city. Above this lies the Harrodsburg limestone which outcrops on the uplands north, south and east of Bloomington, and in the lower portions of the city. Immediately above this formation occurs a stratum about 60 feet thick of Bedford limestone which underlies the surface in the higher portions of Bloomington, and outcrops along the sides of ravines to the north and south of the city. Next above the Bedford limestone lies the Mitchell limestone which outcrops over an area about 4 miles in width, extending west from Bloomington. It is in this latter formation that the present city water supply has been developed. The rocks of this whole region are overlaid on the uplands by a thin, rather impervious soil cover and the alluvial deposits in the valleys are shallow.

[1] Read before the Illinois Section March 23, 1921. Discussion is invited and should be sent to the Editor.

[2] Assistant Engineer, Alvord & Burdick, Chicago, Ill.

The sandstones and shales of the Knobstone are unusually impervious and tough but resist weathering very poorly, and are deeply eroded where exposed. The limestones are in general soluble and are honeycombed with solution channels. This is particularly true of the upper strata of the Mitchell formation.

The geological conditions are in general distinctly adverse to the development of an underground water supply for a city as large as Bloomington, which has a present population of 12,000. In fact, good wells for domestic water supply are infrequent.

The influence of the rocks is evident in the varying topography around Bloomington. To the west in the central portion of the Mitchell limestone outcrop, the uplands are rolling and pitted with sink holes. The water courses are shallow and often disappear into the cavernous limestone, to issue later as springs at the contact plane with less soluble rocks below. Eastward toward the edge of the Mitchell limestone outcrop and beyond, the topography is rough and the streams deeply eroded in the lower limestones, and in the sandstones and shales of the Knobstone formation. The topography in this area offers numerous reservoir sites, but on account of the varying character of the rock formations, they are not all equally desirable from the standpoint of water-tightness. This has been demonstrated by local experience.

Present impounded supply. The two older city reservoirs are located entirely in the cavernous Mitchell limestone formation. The dam of the newer Leonard Springs reservoir rests on Bedford limestone, while the upper part of the reservoir is in the Mitchell limestone.

The experience with these three city reservoirs has demonstrated that a water-tight reservoir should not be expected in these limestone formations, particularly in the Mitchell limestone. At the old reservoirs, leakage occurs in solution channels through which the water finds its way around the dams and under the spillways in natural rock to such an extent that several years ago the entire city water supply was taken from a spring or leak below the lower dam at the main pumping station. When the reservoirs are not full, water not pumped to the city is pumped back into the reservoirs to help conserve the supply. At the newer Leonard Springs reservoir, there is a large marsh immediately in front of the dam with indications of a considerable flow of water from the reservoir above. The leakage from these reservoirs is so great that even though all unused visible

leakage is pumped back into the upper reservoirs, they become rapidly depleted in dry weather. Efforts to correct the leakage have been unsuccessful.

Advantages of Knobstone area. Satisfactory reservoir sites are available in the creek valleys east and north of Bloomington at no greater distance than the existing city reservoirs built in the Mitchell limestone area. In these creeks the Knobstone formation provides an impervious basin which is ideal for retaining an impounded supply, and the narrow deeply trenched valleys afford numerous good dam sites.

In striking contrast to the city reservoirs in the limestone is the very successful reservoir built in the Knobstone formation by the Indiana University for its own water supply. This reservoir was located on the recommendation of Prof. E. R. Cummings, geologist at the Unisity. The reservoir is formed by a concrete arched dam 40 feet in height at the mouth of a small ravine entering Griffys Creek, and has a watershed of about 200 acres. This reservoir is absolutely tight and clearly shows that the City of Bloomington could obtain equally satisfactory reservoirs by utilizing the available reservoir sites in this formation instead of those in the limestones to the west.

The relation of the geology to the water supply of this region has been very fully described in a paper by Professor Cummings. His conclusions are reiterated by the report on the city water supply made by Morris Knowles in 1914, which included a report on the local geology by Prof. W. O. Crosby, geologist at the Massachusetts Institute of Technology. Professor Crosby pointed out the defect of the Mitchell limestone for an impounded supply, and recommended that the city supply be developed in the impervious Knobstone formation.

The new Leonard Springs reservoir was built in the limestone formation subsequent to these recommendations. As above pointed out, this reservoir has repeated the experience with the old reservoirs in the limestone, and Bloomington is again confronted with serious water shortage. The firm of Alvord & Burdick reported on the water supply in 1920 and recommended that the city abandon the reservoirs in the limestone area in favor of an adequate impounded supply in the Knobstone formation.

Deficiency in present supply. Even if the impounding reservoirs of the Bloomington municipal supply were free from leakage, there is good reason to believe that the present development would be

insufficient to fully supply the city during years of greatest drought. There are no records of the local watershed yield but for the purpose of judging the adequacy of the existing development at Bloomington, comparison may be made with the long record of watershed yield at Lexington, Ky.

This latter record covers a period of 26 consecutive years. It is interesting to observe in this record the importance of a long record in determining the safe yield of a watershed, that is, the yield which may be depended upon in the year of greatest drought. If we consider the yield of the driest year in the 26 years' record at Lexington as 100 per cent, the safe yield, as indicated by shorter records which

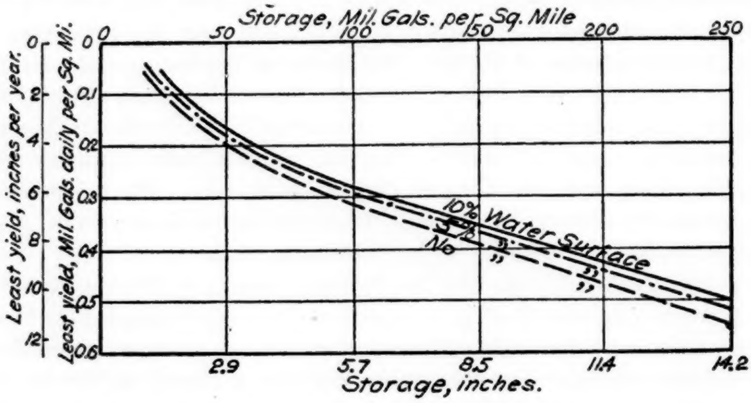

Fig. 1. Relation Between Yield and Storage for Watersheds Adjacent to Bloomington, Ind., Based on 26 Years of Runoff on Hickman Creek at Lexington, Ky.

did not include the driest years, would be as follows, in percentage of the safe yield for the entire 26-year period:

	per cent
Driest year in 26 years	100
Second driest year, once in 18 years	120
Third driest year, once in 15 years	125
Fourth driest year, once in 11 years	160

It is apparent from these figures that the application of a short record of yield in developing an impounded supply may lead to a very serious overestimate of the safe yield.

Figure 1 summarizes the experience at Lexington and shows the safe yield that may be expected from given amounts of storage per square mile of watershed.

At Bloomington the estimated safe yield of the city's impounded supply, based on the Lexington experience, is approximately 1,000,000 gallons per day as compared to a present average pumpage of 1,500,000 gallons per day. It is evident from this that the existing impounded supply at Bloomington is insufficient to provide the city with water throughout the driest year that may be expected. The deficiency might be as much as 80 per cent.

The frequent water shortages experienced at Bloomington are due in part to the fact above pointed out that the development is deficient in safe yield. This deficiency is made more serious by the excessive leakage from improperly located reservoirs.

SOME EXPERIENCE IN THE DEVELOPMENT OF THE OIL ENGINE[1]

By F. B. Leopold[2]

The title of this paper might indicate an intention on the part of the author to impart some knowledge to this Association. It is with regret that he is forced to proclaim that he had no option in selecting the subject. For some inscrutable reason, the Committee of the Water Works Manufacturers Association assigned this subject to a person who knows nothing about an oil engine from a technical standpoint. The author knows what one looks like and also has some idea of the cost of developing a successful engine, and if it be the idea of the Committee that the author should point out ways in which those who have a superfluous amount of the coin of the realm might dispense it, then possibly their object may be accomplished.

It is generally recognized that Dr. Diesel, a German engineer, is the father of the internal combustion engine using heavy oil, and his original patent is dated in 1892, although there were various attempts made in the line of development for many years previous to that time. An engine was actually built in 1680, and although it did not prove a success, it was probably the first step in its development. In 1791, an Englishman, John Barber, built an engine made to use gas distilled from coal, and from that time on to 1866, when Otto obtained his first patent, there were several attempts made. Diesel, however, was undoubtedly the father of the present successfully developed engine. Although his first patents were obtained in 1892, it was not until 1898 that a commercial engine was produced.

In 1898, Adolphus Busch became interested in this engine and secured the rights for the United States. The first engine built was a 60 H.P. unit. During the first few years, however, the progress was very slow and the result unsatisfactory. It is really only in the last ten or twelve years that this type of engine has come into its own

[1] Read at the Cleveland Convention, June 7, 1921. Discussions are invited and should be sent to the Editor.

[2] Pittsburgh Filter Manufacturing Company, Pittsburgh, Pa.

in European countries, and is just beginning to be recognized as the coming power unit in this country. It is altogether probable that the abnormal increase in the price of coal caused by the war conditions was the greatest single element in arousing interest in the heavy oil engine, and has made for a tremendous impetus in its development.

Up to five years ago there were probably not to exceed four or five concerns building internal combustion engines using heavy oil as their fuel. At the present time, there are sixteen builders of Diesel engines and thirty-five establishments building various types of so-called semi-Diesel or low-compression heavy oil engines. Some of them have been on the market for a number of years, and are now turning out engines in large quantities, operating with great success. Others are in various stages of development work.

Among the main successful builders of the Diesel type of engine are the Busch-Sulzer Company, which was the first to engage in this work, The McIntosh & Seymour Company, William Graff & Sons and New York Ship Building Company, which with others, are building engines ranging from 200 H.P. to as high as 2000 H.P. each.

Of the builders of the semi-Diesel type, the concerns longest engaged in this line are the August Mietz Corporation, Fairbanks-Morse Company, Bessemer Manufacturing Company, the Burnoil Engine Company and St. Marys Engine Company. Of the thirty-five concerns building the so-called semi-Diesel engine twelve are operating under the Hvid-Bronz patents, and this is the type of engine that the author has had such experience with as he possessess.

This type of engine is different in its principles of operation from either the Diesel or the semi-Diesel. The essential features of difference are in the method of supplying the fuel. In all cases the fuel is ignited by the heat of compression, but the method of starting and applying the fuel to the various types is essentially different.

In the full Diesel, the fuel is applied with a pump at extremely high pressure through a needle valve through which the fuel is forced by an air pressure varying from 800 to 1000 pounds, which breaks it up into fine particles, so that when the heat of compression is applied it is completely consumed.

In the semi-Diesel, so called, the fuel is dropped on to a pan or bulb which is heated. The fuel is vaporized by the heat. After the engine is started, this bulb is maintained at a high temperature by the heat of compression sufficient to continuously vaporize the fuel, but in starting, it often requires from ten minutes to half an hour to heat

the bulb by a torch sufficiently, so that the fuel will be vaporized when coming in contact with it.

The Hvid-Bronz type of engine draws the fuel into the cylinder on the suction stroke of the engine, or rather it draws it through a small valve into a cup. The compression stroke then heats up this cup and generates a pressure inside of the cup which blows the fuel out and atomizes it into the cylinder, when it is ignited. The semi-Diesel engines operate on a lower compression pressure, but are not as economical in fuel consumption as the Bronz-Hvid or Diesel type.

The author became interested in this proposition by reason of having become interested in a shop which at the time was manufacturing material for war purposes, and it became essential to find some product for permanent development. In looking over the field, the future of the oil engine seemed extremely promising, and it is the author's belief that this industry is just in its infancy.

The great advantage of this type of motor for both stationary and marine purposes is so obvious that temporary discouragement cannot hold back its development. On the other hand, there are many problems to be solved. Those apparently who have given it the greatest technical and practical study of many years, find difficulties which they are unable to foresee, and which, while small in themselves, are of the most vital importance in the successful operation of the engine.

Figure 1 illustrates a four-cylinder engine, the first built by the shop mentioned. The design of the completed engine is exactly as it was on the drawing board, as far as all outward appearances are concerned. All the changes that have been made in the development and experimental work have been entirely in the method of applying the fuel to secure the determined calculated exact distribution and consumption, which means the success in operation and the efficiency of the completed machine.

In the preliminary investigations in the oil engine field, after reaching a determination that this was a promising business, the author, in connection with the engineers, looked over many different types of engines that were being developed and being built. The services of an engineer were secured who had many years experience, both in European and American practice, in the design of Diesel engines, and who, the author believes, is one of the best oil engine engineers in the country.

The company was desirous of looking into future possibilities, and while up to that time the hot-bulb or low-compression type of engine

was most favorably known and had been built and used to greater extent than any other type of heavy oil engine in this country, it was finally concluded that, on account of its higher economy and apparently more satisfactory operation, the Hvid-Bronz type had the greater future promise. This engine is comparatively new but had

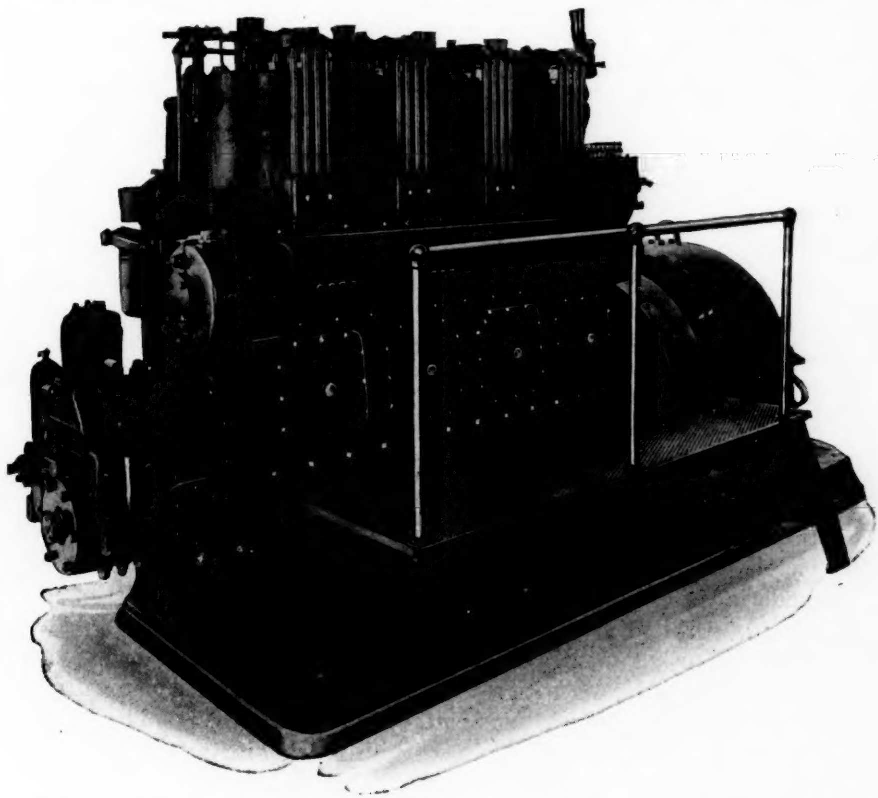

FIG. 1. THE 100-HORSE POWER OIL ENGINE, THE DEVELOPMENT OF WHICH IS OUTLINED IN THE PAPER

been built by one concern for about three years previously, and by one or two others for a shorter period and had been marketed in considerable quantity, and as far as could be learned was giving a very satisfactory account of itself.

Most of these engines were built in small single-cylinder units, although one concern was building a vertical multiple-unit engine

which seemed to be fairly satisfactory. Several others were developing a multiple-cylinder engine of this type. Therefore, after a thorough canvass of the field, a Bronz-Hvid engine of the multiple-cylinder type was selected and it was proposed to build the highest class engine of this type that could be turned out.

A single-cylinder engine of 5 or 6 horse power was purchased and a very long series of experiments made with it with results that were absolutely convincing. Although the engineer felt it was far from perfect, the operation of it was entirely satisfactory from a practical standpoint. This engine would operate on practically any kind of fuel that would flow in it, and, in fact, in the experiments four or five different fuel vessels were attached to the supply line to the engine, ranging from kerosene of the highest grade to the heaviest of crude oil, and it operated apparently equally well on any of them. During the period of operation it was not unusual to switch from one oil to the other.

This engine has no carburetors or electric spark plugs, nothing at all but the compression heat generated in the cylinders to ignite the fuel. The simplicity of its construction and operation was the appealing feature.

The investigation work was cleared up during the war period and the engine completely designed, but no work accomplished until after the close of the war. The patterns were made and the engine built completely in accordance with the designs and not a single change was made in its construction, as far as the general features were concerned. On its completion the engine was started in operation and was apparently a completed piece of mechanism. During this period the coöperation and advice of the patentee were given and on the day of completion with everything ready to place it on the test block for operation, he was more than pleased with the way it started. As the author had never seen an engine start before on the testing block, he was naturally very much elated, as apparently it was going to operate right from the start, and the Company was ready to do business and take orders. However, it was more than a year later before the engineers were ready to place the seal of their approval upon this engine, and during that period many anxious days and nights were spent in endeavoring to determine just what was required to make a successful machine out of it.

The principal difficulty, in fact the only difficulty, was apparently the inability to supply the fuel properly, so that a complete combus-

tion could be secured. In the initial run, although it was believed that the instructions and directions and formulae furnished by the patentee were followed faithfully, the exhaust discharge was a black column of smoke and at night this was superseded by a continual spurt of flame.

It did not require much knowledge of engineering to comprehend that this condition would not allow of operation for a very extended period of time, and in fact a few hours' operation found the fuel cups completely clogged with carbon. Then began the real work, and this dragged over a period of approximately a year.

During this period many engineers were visiting the works and offering suggestions, many who seemed to think that the troubles were trivial and might be corrected in a few days' investigation. The inventor himself, or patentee rather, laughed them away. However, the difficulties were multiplied by the number of cylinders, and the class of machine which it was desired to build.

It was discovered that there was a vast difference between building an engine of a single cylinder which would be satisfactory for ordinary power purposes, or the small factory, oil well or farm, and building a multiple-cylinder engine for a continuous 24 hour service where the greatest nicety of speed regulation was required, and where the possibilities of the engine being out of service at any time must be reduced to a minimum.

The introduction of the fuel into a single-cylinder engine was a comparatively simple proposition. The introduction of an equal amount of fuel into each cylinder of a multiple-cylinder engine, to maintain the same amount of work in each cylinder and thereby maintain uniformity of speed and power, was a very complicated proposition. It was often possible to get practically perfect combustion in one cylinder while the next cylinder could not be operated for any length of time without completely filling with carbon.

Many and various were the methods used for equal distribution of the fuel to the cylinders, for the principle of the Hvid engine is a gravity feed, the fuel being taken into the cylinder on the suction stroke of the engine. With a multiplicity of cylinders the fuel charge would vary in each cylinder, and this method of feed was finally abandoned as it was impossible to get a sufficiently equal charge necessary to secure regulation.

Pumping the fuel against the compression stroke on a somewhat modified principle from the Diesel was then employed and a hundred

other methods were then tried. In the end, a pump was used that is practically a measuring device, using a separate pump for each cylinder, which delivers the oil charge equally to each cylinder valve. It is then drawn into the cylinder on the suction stroke of the engine.

There was an absolute and definite ratio of the size of the cups to be used and the holes through which the fuel was discharged from the cups into the cylinder, and these ratios would vary somewhat with different characters of fuel. The very slightest variation from the determined areas either of the cups or the holes, or the location of the holes, would affect the operation of the engine to a great extent. It was only, however, after experimenting with hundreds of different sizes of cups and methods of adjustment, that a definite formula for making these fuel cups together with the sizes of holes they contain was obtained.

During the period while the engineers were making these various experiments, the author became interested vitally in determining whether this experience was at variance to any great extent from that of others in this line of endeavor. He found that other engine builders visited in the preliminary investigations and who, it was thought, had built marketable engines from the start, had gone through the same grievous experience, in fact, that some had spent thousands of dollars where the author's company had spent hundreds. Several concerns, after spending upwards of a million dollars experimenting on the problems trying to work out a successful engine, had finally been compelled to abandon it. Others had kept on until they had surmounted all difficulties and are now reaping the harvest, and will in the end have their money returned to them many times over.

The only satisfaction that the author has been able to derive from this phase of the matter is that the company was finally able to produce an engine which has been pronounced the finest of the Bronz-Hvid type in this country, and he has no doubt that many concerns entering this field have brilliant prospects of future returns from the money they may invest. He would, however, warn anyone from entering this work with the idea that they will design an engine even on well known principles and expect it to be a success from the start unless they simply reproduce the patterns in detail of some engine that is already on the market. This means that they must provide a large sum that can, if necessary, be devoted to carrying development work to a successful issue.

The possibilities of a heavy oil engine are limitless. In addition to the ordinary uses for central power stations, electric light plants, driving pumping units and general power purposes for marine work, all of which require, of course, units of fair size, there is untouched the vast use for the automobile, truck and locomotive.

The actual cost of producing a horse power of work with the Diesel engine is about one-third the cost of producing it in a steam engine. The initial cost of a power plant for stationary purposes, considering the cost of building, land, boiler and engine, would be practically the same. There are, however, many situations where the space occupied by a steam plant is unavailable. An oil engine will take up on an average from one-half to three-fourths of the same space that a steam engine would occupy, with the entire saving of space occupied by boilers, accessories and coal storage. The oil may be stored in a tank under ground, and the space required for it need no consideration whatever ordinarily.

The oil engine of the Bronz-Hvid type can be started instantly and stopped when you are through with the operation. The steam engine requires time to get up steam, and the fire must be kept ready for service continuously. For marine work, the space occupied in a ship, and the weight of the plant is enormously less, giving the same size vessel the additional cargo space as well as economy in operation. This is being realized very rapidly in marine service, and many ships are now being fitted with this type of motor.

In 1914 there were probably not to exceed twenty motor ships, as as ships driven by oil engines are known. Today there are upwards of 500 and every day sees additions thereto, many vessels of 10,000 to 12,000 tons.

In the April issue of the *Motorship* is given an account of the operation of the 7500-ton motor ship "Borgland," totalling 95,000 miles and nearly 2½ years time without a stop on account of engine trouble. It is stated that

It is a somewhat ironical circumstance that one of the first cargoes that the "Borgland" carried was a load of 7290 tons of coal from Norfolk, Va., to San Francisco, Cal. . . . . . Preference among officers of the merchant marine for motor ships is significant, and in conversation with the "Borgland's" captain . . . . he remarked that the motor ship is far ahead of a vessel driven by steam machinery from the point of view of reliability, and referred to the fact that should one cylinder of the plant of an ordinary twin-screw Diesel engine give out, it is a comparatively simple proposition to put the cylinder out of action and carry on with the remainder at reduced

speed, which is so inconsiderable as to be negligible. As regards fuel tanks, the bulk of the oil is carried in four double-bottoms holding about 900 tons of oil. . . . The fuel consumption is about seven tons per day under normal conditions. It will thus be seen that the ship has a range of nearly 130 days without rebunkering.

As the average speed of this vessel is given at 10 knots per hour, it will thus be seen that she carries enough fuel to travel 31,200 knots, or 35,900 miles, or completely around the world, and nearly one-half the distance further. To do this with coal would leave little cargo space.

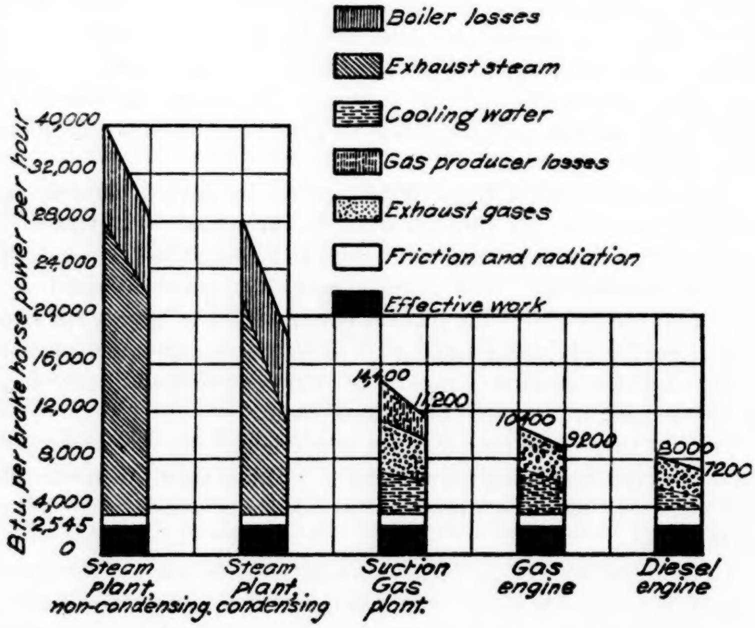

FIG. 2. HEAT BALANCES OF DIFFERENT TYPES OF ENGINES (HERBERT HAAS)

An oil engine will develop a horse power on one-half a pound of fuel oil per hour. A boiler requires four pounds of coal per hour, and some pumping plants require twice that quantity. This means from one-eighth to one-twentieth the weight of fuel to provide for. In times such as we have gone through in the past two or three years, what a strain off the minds of many plant engineers it would be to know that their storage capacity for fuel might be multiplied many times in less space than is now available.

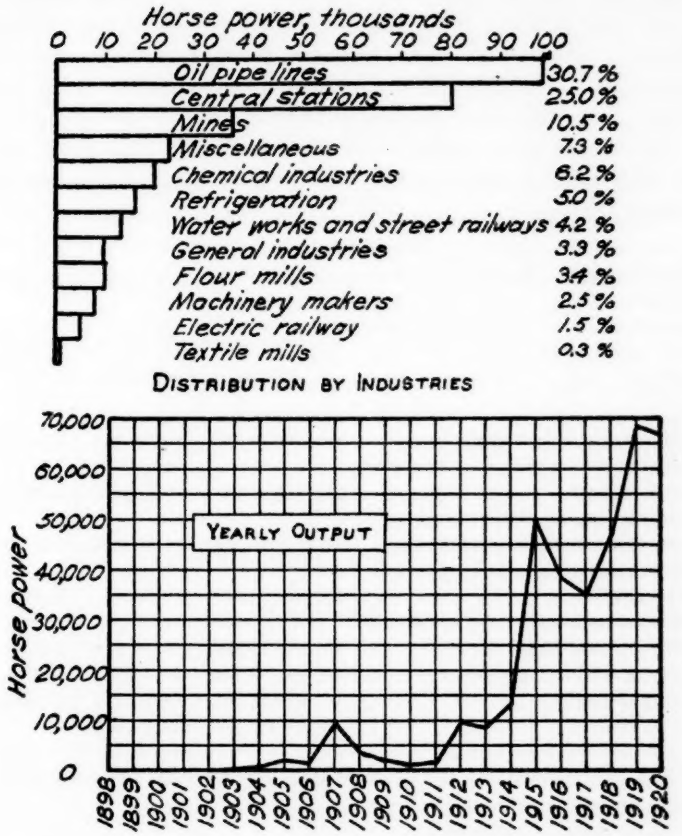

Fig. 3. Diesel Engine Data in the United States. (L. H. Morrison, *Power*, March 1, 1921)

Distribution by states: horse power; New Hampshire, 1350; Massachusetts, 1030; Rhode Island, 550; Connecticut, 400; New York, 9505; New Jersey, 5080; Pennsylvania, 8045; Maryland, 2580; Delaware, 225; Virginia, 2055; South Carolina, 200; Georgia, 200; Florida, 9985; Kentucky, 1490; Tennessee, 100; Alabama, 100; Ohio, 4185; Indiana, 3590; Illinois, 7655; Michigan, 620; Wisconsin, 1865; Minnesota, 2675; Iowa, 2935; Missouri, 10,560; Arkansas, 2120; Kansas, 41,500; Nebraska, 5260; South Dakota, 4350; Louisiana, 12,000; Texas, 62,435; Oklahoma, 39,125; Montana, 420; Wyoming, 3320; Idaho, 460; Utah, 100; Colorado, 1320; Nevada, 780; Arizona, 23,240; New Mexico, 13,950; California, 4940; Alaska, 600; exported to Cuba, West Indies, etc., 23,480.

While this type of engine has not been developed successfully to take the place of the gasoline motor for automobiles, many engineers are working to this end, and it is but a question of time before it is accomplished. Considering the number of automobiles in the country, what a wonderful opportunity there is for the development of this type of motor to replace the gas motor for this work, doing away with electric spark plugs, carburetors, and all the troubles attendant thereto.

TABLE 1

Heat consumption and thermal efficiencies of different types of prime movers at continuous full load

TYPE OF PRIME MOVER	HEAT CONSUMPTION PER BRAKE H. P. HOUR	OVER-ALL THERMAL EFFICIENCY	SUPERIORITY OF DIESEL ENGINE*
	B.t.u.		
Noncondensing steam engine†	40,000–28,000	6.3– 9.1	5.60–3.60
Condensing steam engine using superheated steam†	28,000–16,500	9.1–15.4	3.60–2.30
Locomobile engine with superheated steam and reheater, condensing†	17,000–15,200	14.9–16.7	2.40–2.10
Steam turbine, superheated steam, 200 to 2,000 H.P.†	24,000–15,500	10.6–16.2	3.20–2.20
Steam turbine, superheated steam, 2,000 to 10,000 H.P.†	15,500–14,000	16.2–18.1	2.20–1.95
Gas engine without producer	10,400– 9,300	24.4–27.5	1.33–1.28
Suction gas engine‡	14,000–11,200	18.1–22.7	1.95–1.55
Diesel engine	8,000– 7,200	32.0–35.3	

* Figures in this column are to be used as factors with which to multiply values in preceding column.

† Figures include boiler losses.

‡ Figures include producer losses.

There is also the railway locomotive and this phase is now being considered by one of the largest locomotive builders in the country, which has for the last year or more been studying the possibilities of this engine as a motive power for railroad locomotives. Undoubtedly the time is not far distant when we shall see it in use.

Table 1, giving comparative costs of different prime movers, is from Bulletin 166 issued by the Department of the Interior, Bureau of Mines, and written by Herbert Haas. This bulletin contains some very interesting information on this type of engine, and is recommended to anybody interested in securing real information as to what may be accomplished with the oil engine.

The author has tried to give in a brief general way, without getting beyond his depth, some slight idea of the heavy oil engine, its development, and its possibilities as a power unit. What little knowledge he possesses has been acquired at a very considerable cost, and while he is just as thoroughly satisfied now as he was in the beginning that

TABLE 2

Comparative operating costs of different types of prime movers

*TYPE OF PRIME MOVER	KIND OF FUEL	AVERAGE COST PER 1,000,000 B. T. U.	COST OF 1,000,000 B. T. U. EFFECTIVE WORK	HEAT COST PER ONE EFFECTIVE H. P. HOUR
		cents	*cents*	*cents*
Noncondensing steam engine*	Coal	12	191–132	0.48–0.34
Condensing steam engine using superheated steam*	Coal	12	132–78	0.34–0.20
Locomobile engine with superheated steam and reheater, condensing*	Coal	12	81–72	0.21–0.18
Steam turbine, superheated steam, 200 to 2000 H.P.*	Coal and anthracite	12 11	113–74 104–68	0.29–0.19 0.27–0.17
Steam turbine, superheated steam, 2,000 to 10,000 H.P*	Coal and anthracite	12 11	74–67 68–61	0.19–0.17 0.17–0.155
Gas engine without producer	Natural gas, coke-oven gas or blast-furnace gas	15 7	62–55 27	0.16–0.14 .7
Suction gas engine†	Anthracite	11	61–49	0.16–0.14
Diesel engine	Petroleum	15–18	56–43	0.14–0.11

* Figures include boiler losses.
† Figures include producer losses.

any successful engine of this type will return splendid profits on any investment involved, he also knows that there is much still to be learned. He would advise anyone who may be considering this field, either to acquire something that is completed, or be prepared to spend a fair-sized fortune before expecting to see clear sailing ahead.

TABLE 3

Cost of various types of fuel

KIND OF FUEL	PRICE OF FUEL	HEATING VALUE PER POUND	ABSOLUTE HEAT COST PER 1,000,000 B. T. U.	AVERAGE HEAT COST PER 1,000,000 B. T. U.
		B. t. u.	*cents*	*cents*
Lignite	$1.00 to $2.50, ton of 2,000 lbs.	5,000- 9,000	10.0-14.0	12
Bituminous coal	$2.00 to 4.00, ton of 2,000 lbs.	11,000-14,200	9.0-14.0	12
Anthracite	2.50 to 4.00 ton of 2,000 lbs.	14,500	8.6-13.8	11
Fuel oil (petroleum)	0.75 to 2.25 barrel	18,000-19,000	12.5-37.5	15-18
Natural gas	0.10 to 0.75, 1,000 cu. ft.	900- 1,000	11.0-75.0	15
Blast-furnace gas	0.05 to 0.01, 1,000 cu. ft.	90	5.5-11.0	7
Coke-oven gas	0.02 to 0.05, 1,000 cu. ft.	450	4.4-11.0	7

TABLE 4

Data regarding amount of work performed by different types of pumping equipment

TYPE OF PUMPING PLANT	WORK PERFORMED IN LIFTING WATER	OVER-ALL EFFICIENCY
	foot-pounds per 1 B. t. u.	*per cent*
Steam; good operating conditions	54.5	7.0
Steam; best operating conditions	77.8	10.0
Steam; superheated steam used	93.4	12.0
Suction gas engine; good operating conditions	116.7	15.0
Suction gas engine; special conditions	147.8	19.0
Humphrey gas pump; special conditions	171.2	22.0
Humphrey gas pump; good operating conditions	156.0	20.1
Diesel engine; good operating conditions	225.6	29.0

Incidentally while the author and his associates have an engine that has now been in operation most satisfactorily for nearly a year, they spent a large sum to reach that stage, and had the choice of either stopping where they were, or getting more money. As money has been rather scarce for the last year, they quit for the time being the engine game, to give all their energies to the filter business. The author is more convinced than ever of the truth of the old saying that oil and water don't mix.

RATE OF SOLUTION OF SULPHATE OF ALUMINUM[1]

By J. W. Ellms,[2] A. G. Levy[3] and L. A. Marshall[4]

A knowledge of the time required to dissolve a given quantity of sulphate of aluminum is essential to the proper design of solution and storage tanks required in water purification plants, where this chemical is employed and applied as a solution to the water to be treated. In connection with the design of tanks for a large filter plant for the City of Cleveland, the authors undertook some experiments on a small and large scale with the idea of securing such information as would be necessary to determine the proper size for these tanks.

In 1897, A. A. Noyes and W. R. Whitney[5] showed that the rate of dissolution of a solid in a solvent was an extremely rapid process, but that the rate of diffusion of the solution formed was comparatively slow. It is the slower diffusion which determines the observed, i.e., the apparent, rate of dissolution of the solid. These investigators concluded that the solid substance when immersed in the solvent immediately became surrounded by a very thin layer of saturated solution, which slowly diffused into the solvent not in contact with the solid. Their hypothesis was fully borne out by their experiments, and has been confirmed since by other investigators.

Obviously there are several important deductions which may be made from these general principles:

(1) The greater the surface area of the solid to be dissolved, the larger the quantity of saturated solution there will be ready for diffusion into the body of the solvent.

(2) The more quickly the saturated surface layer can be removed by diffusion, the more rapidly will a new surface layer form.

[1] Presented at the Cleveland Convention, June 7, 1921. Discussion is desired and should be sent to the Editor.

[2] Engineer of Water Purification, Cleveland Water Department.

[3] Assistant Engineer, Cleveland Water Department.

[4] Chemist, Cleveland Water Department.

[5] Zeitschrift physik. Chem., 23, 689, 1897.

The practical conclusions are, therefore, (*a*) that the solid should consist of many small particles, i.e. be finely ground or crushed; and (*b*) that diffusion must be hastened by the utilization of some extraneous force.

The application of these general principles to the problem of dissolving a given amount of sulphate of aluminum within a definite time, in correctly proportioned tanks, and with the utilization of a minimum amount of energy, was the basis of the experimental work.

Two general methods of producing solutions are at once apparent: (1) The movement of the solute in the solvent, and (2) the passage of the solvent through the mass of the solute. The first condition is exemplified in the ordinary mixing tanks containing motor-driven paddles and rakes; while the second is illustrated by the upward passage of water through the channels formed between the lumps of the chemical to be dissolved.

The mechanical agitation of the solid in the solvent by means of motor driven stirrers has certain obvious drawbacks. From the operating standpoint, power is constantly required, the alum solution is more or less corrosive in its action on metals, and the motors and machinery require some degree of skilled attention. From the point of design, the stirring machinery must be of rather heavy construction and the motors of relatively large capacity, especially if large amounts of alum are charged into the solution tanks at once or at frequent intervals. This means high first cost and consequently high interest and depreciation charges. In view of these facts, it was felt that a better method of producing solution, provided the plan was found practical for use on a large scale, would be to rely on a continuous flow of water up through the solid, the latter being supported on a grid in the solution tank. By this method, distribution of the saturated layer into the body of the solvent would depend upon the movement of the water as it made its way upward through the ground or crushed alum.

If the latter method is followed, however, it is evident that the total quantity of water used must not be greater than will just fill the storage tank into which the solution is discharging. Provided the chemical can all be dissolved in the time required to fill the storage tank, the rate of application of the water may be varied between rather wide limits. These limits range from that of practically instantaneous filling of the tank on the one hand, to that of partly filling it on the other. There still must be allowed, however,

a sufficient margin of time, before cutting the tank into service, so that the completion of the filling may be made rapidly from an auxiliary source of supply.

With these limitations in mind, and assuming the desired capacity in the storage or supply tank for the finished solution, and a solution tank of sufficient size to hold the alum charge to be dissolved, the problem is, will it be possible to dissolve all of the alum by the time the storage tank is full?

Several different pieces of experimental apparatus were constructed for measuring the dissolution velocity of the alum. In each apparatus, however, the principle of an upward flow of the water through the alum supported on a grid, was used. The principal apparatus consisted of a wooden box with inside dimensions of 4 inches by 4 inches by 70 inches in height. A perforated wooden grid was

TABLE 1

Effect of change of size of alum on rate of solution, expressed as height in inches of column of alum at different stages of the experiment. Rate of flow, 5.04 inches vertical rise per minute. Temperature, 10°C.

STAGE OF EXPERIMENT	LUMP, COARSE AND FINE AS RECEIVED	PASSED ¾ INCH MESH LEFT ON ½ INCH	PASSED ½ INCH MESH LEFT ON ¼ INCH	PASSED ¼ INCH MESH
Start	29⅜	30½	31	27¼
After 10 minutes	25	22¼	18	6
After 30 minutes	16⅜	8½	3¾	1
After 60 minutes	8⅞	⅝	⅛	0
After 90 minutes	3¾	0	0	
After 120 minutes	1⅜			

placed 13 inches above the bottom. Overflow pipes were provided on one side near the top. The water was admitted to the chamber underneath the grid.

Usually a column of lump alum about 30 inches in height was placed in this device, and the time required to dissolve it at different rates of flow, was determined. The rates of flow used varied from 2.52 inches to 10.08 inches per minute, corresponding to tanks in the proposed design that would be filled in 4 hours to 1 hour. Intermediate rates of 3.36 inches and 5.04 inches vertical rise per minute (corresponding to 3 and 2 hours, respectively, for filling the tank) were also tried. Graded sizes of alum were experimented with and showed clearly the effect produced by increasing the surface area of the solute exposed to the solvent. The results given in table 1 will show this effect.

Experiments made on two pieces of alum set in paraffin, which maintained a practically constant surface area exposed to the water, but whose actual areas differed in the ratio of 1 to 4, showed losses in the same ratio when exposed to water flowing at the rate of 6.3 inches per minute. It was also found that if the water flowed past these pieces of alum at a rate four times as fast, the actual loss and the ratio of the losses from the pieces, was practically the same as at the lower rate of flow. This would indicate that the quantity of alum dissolved in any given time is directly proportional to the area exposed to the solvent, and, within the rates of flow which were em-

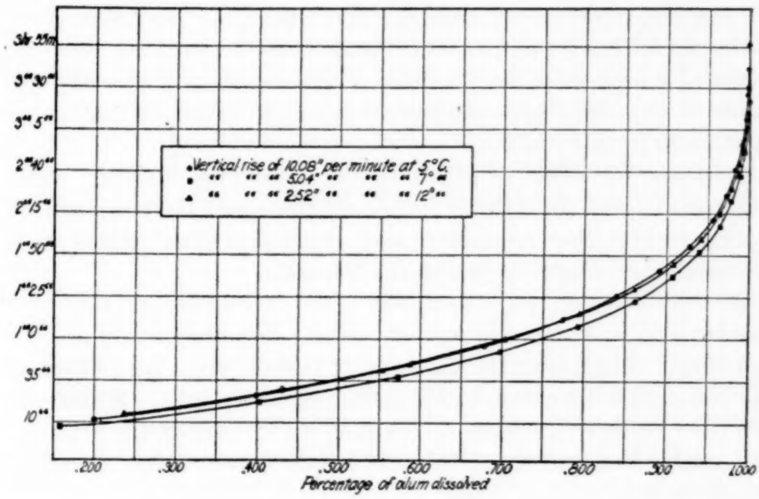

Fig. 1

ployed, practically independent of the velocity. In other words, the rate of diffusion was not appreciably affected by the variation in the vertical rise of the water used.

This relationship is also well brought out in the set of curves shown in figure 1. For three different rates of flow, practically the same proportion of the total charge was dissolved in equal lengths of time. The reason for the curves not coinciding exactly is probably due to the fact that, in addition to the temperature variation, the experiments were made with run of crusher alum, in which the ratio of surface to volume was not the same due to variations in the proportions of the different sized pieces.

The effect of temperature on the rate of dissolution was studied experimentally on pieces of alum 25 mm. square set in paraffin, as previously explained, and subjected to the action of water flowing at the same velocities but at differing degrees of temperature. One set was run through at a temperature of 4°C. and another at a temperature of 23°C. At 4°C., the loss per square mm. was 0.00418 grams, and at 23°C., it was 0.00828 grams. In other words, with a difference of 19°C., the rate of dissolution at the high temperature was nearly twice as fast as at the low temperature. Two other experiments, which had been run for different purposes, at approximately 7°C. and 13°C., showed losses per square millimeter which fell approximately on the straight line connecting the losses given above for 4°C. and 23°C. This would seem to indicate that the effect of temperature on the rate of dissolution is a straight line function, increasing approximately 5 per cent per degree Centigrade increase in temperature.

To study the effect of depth on the dissolution velocity, water was first passed through 30 inches of alum and then through 15 inches, and the time required in each case to completely dissolve the chemical was found to be practically the same.

In order to carry out experiments on a large scale, a perforated wooden grid was placed in a steel tank 6.5 feet in diameter and 3.5 feet deep. The top of the grid was 11 inches above the bottom of the tank, and the overflow 25 inches above the grid. Water was admitted to the under side of the grid. The area of the grid was 33.5 square feet, and was filled with $\frac{3}{4}$ inch circular holes, placed on 3-inch centers.

Two tons of crushed alum were placed on the grid, and water forced up through the mass. The alum stood at a depth of 16.5 inches before applying the water. The water was forced up through the alum at a rate of 2.5 inches per minute. At the end of 15 minutes, the pile of alum had diminished in depth 6 inches, at the end of 30 minutes, 11 inches, and at the end of an hour, 15.5 inches. At the end of two hours, the tank was drained, and all that was found on the grid was 6 pounds of wet gummy matter, which covered a considerable area of the boards to a depth of $\frac{1}{4}$ to $\frac{1}{2}$ inch. This material readily dissolved on a wire grid when placed in a glass cylinder, showing that it was soluble, if the dissolving water came in contact with it in the proper way. Hosing this gummy residual matter, which was left in the tank in a second experiment, showed

that it could readily be dissolved if the hose stream had force enough to disintegrate it. The practical conclusion is, that the grid must be properly designed so that, while it will support a load of alum of the desired fineness, it will still permit of an upward flow of water at as many points as possible, leaving as few dead areas as practicable.

The conclusions reached in this investigation are as follows:

1. That basic sulphate of aluminum in lump form as ordinarily sold, may be readily dissolved in upward flow solution tanks in a reasonable length of time.

2. That, where such tanks are used with a vertical rise of water at a rate of 2.5 to 10 inches per minute, and a temperatue of about 7°C., run of crusher alum, having pieces not exceeding 2 to 3 inches in diameter, may be completely dissolved in from 3½ to 4 hours.

3. That, under the same conditions as in the preceding statement, but at a temperature of 10°C., crushed alum with sizes of pieces varying from ½ inch to ¾ inch may be dissolved in practically 1½ hours, while pieces ¼ inch to ½ inch in diameter may be dissolved in one hour.

4. That the rate of dissolution, or more properly diffusion, was not materially different for the rates of flow used, namely 2.5 to 10 inches vertical rise per minute.

5. That, for all practical purposes, provided the point of saturation is not reached by the solvent (water) in passing through the column of alum in upward flow tanks, within the limits of these experiments, viz: 2.5 to 10 inches vertical rise per minute, the length of time required to dissolve alum in any given condition is a factor only of the temperature of the water and of the size of the pieces of alum, and is independent of the total weight of alum to be dissolved.

6. That the depth of alum which may be used in upward flow tanks without the solvent becoming saturated before reaching the top, may be determined approximately (keeping in mind the experimental limits of vertical flow) from the results obtained, namely, that run of crusher alum dissolves, in water having a temperature of about 7°C., at the rate of approximately 2 per cent of its depth per minute; alum crushed to the size of ½ inch to ¾ inch pieces, using dissolving water at a temperature of 10°C., at approximately 4 per cent of its depth per minute; and alum composed of pieces ¼ inch to ½ inch in diameter, using the same temperature (10°C.) of the

dissolving water, at a rate of approximately 7 per cent of its depth per minute. With a depth of alum of approximately 5 to 6 inches, and which has been crushed finer than $\frac{1}{4}$ inch, the solvent will become saturated by the time it reaches the top of the column, when the vertical rise is 5.04 inches per minute and the temperature 10°C.

7. That, for each degree Centigrade change in temperature, the rate of dissolution of alum, and consequently the time required to dissolve the alum, will vary approximately 5 per cent, the time decreasing with an increase in temperature.

8. That, with a knowledge of actual velocity of solution under the practical conditions imposed in these experiments, it becomes a comparatively easy matter to properly determine both the actual and relative sizes for the solution and storage tanks.

9. That the design of the grid supporting the alum should be such as to leave as few dead areas as possible.

THE DIVISION PUMPING STATION AT CLEVELAND, OHIO, AND ITS OPERATION[1]

By J. N. H. Christman[2]

Actual work to give the City of Cleveland its first water department was started in the year 1854, when the population of the town was approximately 30,000. The installation consisted of a pumping station on Division Avenue equipped with two Cornish pumps, each having a capacity of 4,000,000 gallons per day. The water for these pumps was drawn through an inlet pipe 50 inches in diameter, situated 300 feet west of the old river bed and extending out into the lake 300 feet, connecting at the shore with a 5-by-4-foot brick aqueduct. The discharge from these pumps was carried to a reservoir of 6,000,000 gallon capacity and 158 feet elevation, on Franklin Avenue at Kentucky Street. The piping system consisted of 13 miles of pipe of various sizes. The cost of this water supply system was $513,600 and it was considered ample for 200,000 inhabitants and adequate for the next 50 years. Water was first turned into the mains on September 19, 1856.

Work was begun on Cleveland's first lake tunnel in 1869, when the population of the town was about 86,000. This was a 5-foot tunnel which was built at the point of the old aqueduct at the lake shore to an intake crib located in Lake Erie 6600 feet from the shore and approximately the same distance west of the Cuyahoga River. The capacity of this tunnel was estimated as 40,000,000 gallons per day. The salient feature in the construction of this tunnel was the change in the location of the water intake from about 300 feet from the shore to a mile and a quarter. This change of water inlet was necessitated by the pollution of the shore water due to the rapidly growing town. In the meantime Division Station was enlarged by building a new boiler and engine house. Two 10,000,000-gallon pumping engines were erected in the new building and additional

[1] Presented at the Cleveland Convention, June 7, 1921. Discussions are invited and should be sent to the Editor.

[2] Mechanical Engineer, Cleveland Water Department.

water mains were laid throughout the City. The total pumping capacity of the station was now 28,000,000 gallons per day. This was not actual pumping capacity, however, because it was discovered that when either of the new 10,000,000-gallon engines was in operation, the two Cornish pumps could not be run on account of the suction of the large engine lowering the water in the wells so that the suction of the Cornish pump was uncovered.

About 1876 the mode of supply to the consumer was changed. Water was pumped directly into the mains, with the reservoir floating on the line and being used for pressure regulating and water supply equalizing purposes only, taking the surplus pumpage and making up deficiencies in pumpage instead of receiving the water directly from the engines and supplying the consumers by gravity. About six years later the water consumption had increased to such a point, due to growth of the City, that work was started on the new low-service reservoir at Fairmount Station, and the first high-service reservoir at Kinsman Road. Additional buildings and pumping machinery were installed at Division Station, and about 92 miles of feeder and distributing mains were laid. These improvements established the low and high-service pressure zones. With the city's rapid growth and the consequent increase in water consumption, the capacity of the 5-foot tunnel was insufficient, so in 1888 work was begun on the second lake tunnel. This was a 7-foot diameter tunnel extending from the old West Side intake crib to Division Avenue Station. Its capacity was estimated at 110,000,000 gallons per day, which with the 5-foot tunnel gave the City a capacity of 150,000,000 gallons per day. The pumping capacity from Division Station had been, in the meantime, increased to 70,000,000 gallons per day.

The population in 1891 was 272,000. This shows how far the City exceeded the growth expected at the start of the waterworks system in 1854, when it was thought that the little 50-inch lake inlet tunnel would supply the City for 50 years.

The addition of boiler rooms and engine rooms to Division Station necessitated by the increase in water consumption made the station very unwidely, so that in 1896 it was decided to provide the City with a duplicate system of water supply, and work was begun on the 9-foot east-side tunnel. Accidents delayed the completion of this until 1903, and in the meantime the new Kirkland Station had been completed and the necessary water mains laid, so that on

February 11, 1904, Kirkland Station went into service and the old Division Station shut down until the west-side tunnels could be extended further into the lake.

Immediate extension of the west-side tunnels was intended upon the completion of the east-side system. A new tunnel was to be built from Crib 4, 16,000 feet northwesterly to a new intake crib to be located four miles from shore. In the year of 1901, while the east-side tunnel was under construction, a radical change was made in the method of delivering water to consumers by metering all services. Prior to this date, water for manufacturing, commercial aud other business purposes was the only water metered, being only 6.42 per cent of the total water consumed. This small percentage, however, of metered service brought in 42 per cent of the total revenue. The effect of this general application of meters was to so reduce the consumption of water as to defer the need of extending the west-side tunnels for the time being.

The daily average consumption in 1901 was 69,600,000 gallons, equal to 170 gallons per capita per day. This consumption steadily decreased as the number of meters installed increased, until 1908 when the average daily consumption was 52,000,000 gallons. In 1909 the daily consumption was 52,800,000 gallons, equal to 97.8 gallons per capita per day. In other words the daily per capita consumption, by metering all the service, had fallen from 170 gallons in 1901 to 98 gallons in 1909, the population in the meanwhile having increased from approximately 396,000 to 540,000. From then on, the rapid growth of the city overbalanced the saving effected by the meter system, and the daily consumption again began to increase. It was therefore decided to proceed with the work of extending the west-side tunnels.

The plans for the work provided for 16,000 feet of 10-foot tunnel running northwesterly from the junction of the old 5- and 7-foot tunnels at Crib 4 to the new intake crib to be located four miles from shore. Bids for the work were received three different times and rejected in each instance as being too high. After the receipt of the last bids, the lowest which was $1,068,000, exclusive of the intake crib, for which a separate contract was let, the city decided to build the tunnel by direct labor. In the meantime, the crib for the intake shaft had been built and placed in position in Lake Erie.

Preliminary work on the tunnel was begun in May, 1913, which consisted of filling in a swamp on Whiskey Island, building a roadway, and boat landing on the same, installing a storehouse, power plant, etc. In March, 1913, a disastrous flood carried such an amount of silt into the lake that it remained in suspension for two or three months. The turbidity remained for so long after the flood that the Mayor of the City became convinced that a filtration plant was necessary, and a commission was appointed to investigate and recommend the type of filter plant which was best suited for Cleveland's needs. On January 27, 1914, actual work was begun on the filter plant in accordance with the commission's recommendations. The entire work, with the exception of the final examination and test of the structure, was completed by February, 1916. The building of the filtration plant necessitated an entirely new station at Division Avenue with the necessary piping changes for the same.

Investigations at the time the city was completing the east-side tunnel by direct labor, and expert testimony in a lawsuit occasioned by the City taking the tunnel work away from the contractor, recommended that the tunnel should be unwatered as soon as possible and repaired if it was to be used further. This was the reason for the first filtration plant being built on the west side. When it was finally decided that filtration of the city water was necessary, plans were laid to proceed as follows:

1. A filtration plant of 150,000,000 gallons daily capacity to be built next to the Division Avenue pumping station.
2. To entirely rebuild the old Division Avenue pumping station.
3. To install three new service pumps, overhaul and rebuild three old vertical triple-expansion crank and fly-wheel pumps at the station, and to move the 30,000,000 gallon DeLaval turbine pump from Kirkland to Division Station.
4. To install three low-lift pumps with a total capacity of 260,000,000 gallons for furnishing the filter plant with raw water from the tunnels.
5. To install the necessary water mains.

All this work was to be done in the shortest possible time. The Kirkland pumping station was then to be shut down and the east-side tunnel unwatered, examined, and repaired, if necessary. While Kirkland was shut down, a new filter plant should be built in connection with it.

The final plans of the new station showed a T-shaped ground plan layout. The main engine room is approximately 226 by 73 feet, inside dimensions. The north pavilion or low-lift pump room is on the north end of the main engine room and is approximately 148 by 52 feet, inside dimensions. The boiler room adjoins the east side of the main engine room and is approximately 100 by 96 feet, inside dimensions.

Bids were received, contracts let and actual work was started in the fall of 1914. Three new service pumps were purchased, two of 25,000,000 gallons capacity at 250 feet head for low-service pumping, and one of 20,000,000 gallons capacity at 400 feet head for first high service pumping. The Allis-Chalmers Company was the successful bidder for the new pumps, and also for the rebuilding of the three old pumps, which consisted of one 20,000,000-gallon low-service engine called Allis No. 1; one 20,000,000-gallon low-service called Kilby No. 1, and one 10,000,000-gallon first high-service engine called Holly No. 1. The rebuilding of these three old engines was necessitated by the decision to use 200 pounds steam pressure and 100° superheat.

The Dravo-Doyle Company was awarded the contract for furnishing three low-lift centrifugal pumps, two of 100,000,000 gallons per day capacity and one of 60,000,000 gallons capacity, each capable of delivering their ratings at 50 feet total head.

Foundations for eight 500 horsepower boilers were put in the new boiler room, but only five were purchased. These are four-pass Stirling boilers furnished by The Babcock & Wilcox Company. A sixth boiler had been installed since, but to date has not been put on the line. All boilers were equipped with 6-retort Riley stokers and each boiler has its individual stoker engine and fan. There is also an individual coal weighing hopper, recording flow meter, 3-in-1 draft gage, recording pyrometer, etc., for each boiler.

Overhead storage bins of approximately 1080 tons capacity were provided. These are served by two Link-Belt conveyors which carry the coal from the outside hopper under the railroad track to the bins. These two conveyors also handle the ashes carrying them to a bin over the railroad track and permit an easy removal of the ashes in a standard coal car.

Two stacks, each 228 feet high by 9 feet diameter, carry away the products of combustion.

Two Kerr-Worthington centrifugal pumps and one Epping-Carpenter horizontal compound duplex pump were provided for boiler feeding. These pumps are supplied by a 4000 horsepower Cochrane open feed water heater. A Moore-Manistee centrifugal pump has since been installed.

The necessary piping was provided for and in addition test condensate and exhaust pipes were carried to the feed water heater, which was so fitted that a complete individual test could be run on any pumping unit or boiler without disturbing station operation.

TABLE 1

The following guarantees were made and results obtained on duty trials on the different pumping units

ENGINE	GUARANTEED DUTY PER MILLION B. T. U.	TEST DUTY PER MILLION B. T. U.	TEST DUTY PER 1000 LBS. STEAM
Service pumps:			
Allis No. 1 (rebuilt)		171,319,822	207,837,683
Allis No. 2	170,000,000	171,123,384	204,767,090
Allis No. 3	170,000,000	171,279,745	206,202,770
Kilby No. 1 (rebuilt)		157,619,666	189,895,399
Holly No. 1 (rebuilt)		169,610,398	201,580,840
Allis No. 4	170,000,000	173,802,905	211,540,084
Low-left pumps:		*Operation*	
DeLaval No. 2	153,700,000	Bleeding	154,294,000
	127,825,000	Non-bleeding	128,319,000
DeLaval No. 3 and 4	160,937,000	Bleeding	169,231,000
	130,250,000	Non-bleeding	132,479,000

A small 100 kilowatt unaflow engine generator set was installed, which supplies the station and filter plant with necessary current. The municipal electric light current was brought in as a standby.

Machine tools for routine repair work only were provided.

The station was completed in 1917, but trouble was experienced with the clear water reservoir which provides suction for service pumps. As the suction of the two first high-service pumps was connected into the low service main from Kirkland station, it enabled the 10,000,000-gallon Holly to be started in June, 1917. The completion of repairs to the clear water basin permitted the remainder to be put in service and the last engine, Allis-Chalmers No. 4, was put on the line February 2, 1918.

Duplex condensate pumps, float controlled, replaced the plunger condensate pumps direct driven from the air pump on all the low lift pumps.

All pumps and boilers either met or exceeded their guarantees so there were no controversies on the subject. (See table 1.)

Test duties are actual results, uncorrected for superheat.

Guaranteed duties are the averages of guarantees for 50° and 70° circulating water.

Average duties figured giving duty at 100 per cent rating twice the weight of duties at 60 per cent and 115 per cent.

Average of bleeding and non-bleeding duties figured giving bleeding duties 7 points and non-bleeding duties 3 points.

The cost of each of these three low lift units was $41,700.

An interesting feature in connection with the triple expansion pumps is the cost of the different units as shown in table 2.

TABLE 2

Cost of triple-expansion pumps

NAME	NUMBER	COST	CAPACITY M. G. D.	DATE ERECTED
Holly	1	$115,700	10	1901
Allis	1	64,350	20	1899
Kilby	1	131,500	20	1902
Allis-Chalmers	2	84,500	25	1915
Allis-Chalmers	3	84,500	25	1915
Allis-Chalmers	4	90,000	20	1915

Guaranteed efficiencies of boiler, furnace and grate and test results were as follows:

Rating	100	150	200.0
Guaranteed efficiency	77	75	70.0
Test Efficiency	79	81	72.5

As the superheat obtained was such that the steam temperature was nearly 600°, to which the vertical triple expansion engine builders objected, 13 of the 40 superheater tubes were removed from each boiler, leaving about 319 square feet of superheating surface from which the desired steam temperature of 500° is obtained.

The five boilers, including brickwork, cost $43,514 and the stokers $19,000. This figures out about $25 per boiler horsepower installed, which is less than 50 per cent of what was paid per boiler horsepower for the last installation at this station.

Throughout a year's operation, the boiler-room efficiency averages very close to 75 per cent and table 3 shows results obtained for the year 1920 with coal costing \$4.60 per ton at the stations.

During 1920, 22,215,000,000 gallons were pumped into the low-service mains against an average head of 191.4 feet, and 7,497,000,000 gallons were pumped into the high-service mains against an average head of 367.8 feet. This total is 57.8 per cent of all the water pumped from the lake, and it cost \$11.43 per million gallons to pump it.

The station showed an average overall duty of 117,000,000 foot-pounds per 100 pounds of coal based on water handled and coal consumed, no corrections being made for steam supplied the filter plant, some of which is live steam and some exhaust. In the summer, with no heating load on the plant and a maximum demand on the pumps, a duty of 126,500,000 foot-pounds is reached.

TABLE 3

Results of boiler room operation, 1920

Total steam generated	514,635,380.00 pounds
Total coal consumed	60,909,615.00 pounds
Actual evaporation as fired	8.46 pounds
Cost of coal per 1000 pounds steam	28.200 cents
Operating labor cost per 1000 pounds steam	8.620 cents
Routine repairs, labor cost per 1000 pounds steam	1.306 cents
Routine repairs, material cost per 1000 pounds steam	2.894 cents
Total cost per 1000 pounds steam	41.020 cents

In order to keep the station equipment at its highest possible efficiency, the station chief works in conjunction with the mechanical engineering department. Check tests are run from time to time, gages and venturi meters are continually checked, and any piece of apparatus becoming unsuitable or showing undue wear or breakage is replaced by something better, if possible.

Upon completion of the installation of the new 20,000,000 gallon per day DeLaval turbine, the station will have a 50,000,000 gallon per day capacity for first high-service pumpage. There is at present 90,000,000 gallons per day capacity for low-service pumpage and room for one more pump. The low-service demands are such that a new pump will probably be purchased in the near future. After its installation, Division Station will have reached its limit in capacity.

A brief description has been given of the Division Station of the past, but what the Division Station in the future will be, cannot be determined now, as obsolescence determines pumping station life. All the conditions in the stations are not ideal. If the station were rebuilt now, some changes would certainly be made, but at the same time it is felt that it is a very efficient station, which will do good work for many years to come.

OPERATION OF THE WATER FILTRATION PLANTS AT EVANSTON, ILLINOIS, AND WHITING, INDIANA[1]

By Samuel A. Greeley[2]

The filtration of the public water supplies from Lake Michgan in the vicinity of Chicago along the southwestern shore line is becoming more general. Already filter plants have been put into operation at the following places:

Illinois, Great Lakes, Fort Sheridan and Evanston,

Indiana, Whiting and East Chicago.

In addition, a plant is under construction at Winnetka, Ill., and the installation of filter plants is under active consideration at Waukegan and Highland Park and elsewhere along the shore. From these filter plants, filtered water is also supplied to the villages of Wilmette and Glencoe. All present indications point to the conclusion that within the next few years practically all of the public water supplies from Waukegan to Gary will be supplied with filtered water except possibly Chicago. It is interesting, therefore, to make some brief mention of operating experience at some of these filter plants.

Characteristics of Lake Michigan water. No comments on filter plant operation are complete unless the characteristics of the raw water are stated. In Lake Michigan, as is common elsewhere, changing characteristics prevail. The temperature varies with the season, the turbidity with the weather, and the microscopic organisms irregularly chiefly during the warmer months of the year. However, there are also certain marked variations in the character of the raw water produced by the differing populations along the shore. The principal difference is between the shore line north of Chicago and that south of Chicago. At Waukegan, north of Chicago, we find a present moderate industrial development which is likely to increase but, with this exception the north shore line is principally residential. Within Cook County, most of the sewage

[1] Read before the Illinois Section, March 23, 1921. Discussions are invited and should be sent to the Editor.

[2] Consulting Engineer, Pearse, Greeley and Hansen, 39 West Adams Street, Chicago, Ill.

has been diverted from the Lake, with the exception of some storm sewage, so that foreign substances of industrial origin difficult to remove are not found. The filter plant at Evanston is typical of this condition.

Along the shore south of Chicago, on the other hand, we have one of the most intensive industrial developments in the world. An immense volume of industrial sewage is produced, estimated roughly at over 500,000,000 gallons per 24 hours. This discharges into the Lake and into the waterways of the Calumet District. The industries are varied from cement mills to chemical works but are predominantly oil and metal industries. Both of these industries produce considerable volumes of coal tar and petroleum wastes which impart tastes to the water supplies of a most persistent character. Due to the influence of these industrial discharges the character of the lake water along the south shore appears to vary within comparatively short distances of from two to three miles. There are in this district recently completed water filtration plants at Whiting (population 12,000) and East Chicago (population 40,000), Indiana. Along the south shore it may be noted that the lake water is shallower than further north so that higher turbidities are somewhat more prevalent.

In general it may be said of Lake Michigan water that the alkalinity is relatively constant although not always responsive to good coagulation with alum and that the other characteristics such as turbidity, organic matter, bacteria, etc., are changed very rapidly and to a large degree by sudden shifts of the wind. In fact, increases in the organic content of several hundred per cent have been noted within a few hours.

Special local factors. Not only are characteristics of the lake water changing from day to day and season to season but there is also a gradual change resulting from local community developments. Thus it is believed that the load of pollution along the Lake County shore in Illinois will soon be decreased by the construction of sewage treatment works under the direction of the Trustees of the North Shore Sanitary District. The development of local factors along the south shore is not so clear although the load of domestic and industrial sewage pollution will decrease with the final reversal of the Calumet River by the completion of the Calumet-Sag Channel expected during 1921. There is need, however, for a comprehensive study of local factors influencing the public water supplies along the south

shore particularly as regards tastes from industrial sewages. Four factors stand out:

a. The location of sewer outlets.
b. The location of water intakes.
c. The treatment of the sewage (including plant processes).
d. The treatment of the water.

The problem will eventually be solved by the economic adjustment of these factors from the community standpoint. It is probable that the treatment of the industrial sewages of large volume will be a costly project although an easy adjustment of plant processes can sometimes be made. The construction of water purification plants is considerably less costly because the water supplies are small in volume as compared with the sewage, and is called for, in any event, as the first line of defense against bacteriological pollution, turbidity and other objectionable qualities of the raw water.

Operating problems. In addition to the usual routine problems of operation those which have called for special study relate to occasional difficulties of securing adequate coagulation; the shortening of filter runs due to the growth of microscopic organisms in the lake and the removal of tastes coming principally from industrial discharges.

The problem of coagulation is always important in filter plant operation and is particularly so at the filter plants in this vicinity at times of operating trouble resulting from algae growths or industrial pollution. The control of algae growths in the lake appears to be impossible and plant operation must therefore be adjusted to meet the difficulty when it occurs. The principal effect is to shorten the filter runs and occasionally to impart a slight residual taste to the filtered water. The problem of taste removal has already been pointed out as one of major community importance involving a number of controllable factors, not directly connected with filter plant operation.

Filter plant elements. In this brief review of filter plant operation reference is made in particular to the plants at Evanston, Whiting and East Chicago. The principal elements are given in table 1.

The plant at Evanston, as originally designed, had a rated capacity of 12,000,000 gallons daily and was operated near that rate for a number of years prior to the installation of meters. It is now being operated at about half its rated capacity. The original period in the coagulating basins of 1 hour and 40 minutes on rated capacity

was relatively short, but is now increased to about 3½ hours. The plant is of standard design with high rate wash, the wash water coming from a storage tank.

The filter plant at East Chicago with a rated capacity of 8,000,000 gallons daily has been in service for about 4 months and is being operated at slightly above rated capacity (8,600,000 gallons daily). The plant is typical of rapid filter design, with a period in the coagulating basins of 3.75 hours and with high rate wash from an elevated tank.

The plant at Whiting differs from the others by the addition of an aerating basin through which the water passes prior to entering the coagulating basins. The coagulating basins provide 4.23 hours displacement at rated capacity of 4,000,000 gallons daily and the plant is being operated at a slightly lower rate. High rate wash is

TABLE 1

Elements of water filtration plants along Lake Michigan near Chicago

PLANT	INTAKE		PLANT CAPACITY	SETTLING PERIOD	OPERATION WINTER 1920-21	
	Length	Depth			Quantity	Capacity
	feet	*feet*	*m. g. d.*	*hours*	*m. g. d.*	*per cent*
Evanston	5600	30	12.0	1.7	4.8	40.0
Whiting	2400	20	4.0	4.23	3.9	97.5
East Chicago	3000	20	8.0	3.75	10.0	125.0
Winnetka	3000	20	3.0	3.8	*	*

* Under construction.

provided from a wash water pump. The plant includes a high lift pumping station which is electrically operated.

Operating routine. It is particularly interesting in the first place to compare the length of run at the various filter plants. The plant at Whiting has been operated at around 3,800,000 to 3,900,000 gallons daily or just below its rated capacity. With that load on the plant the runs during January were 8 hours with alum at 1.5 grains per gallon and in addition lime at the rate of 0.7 grain per gallon. In February the runs were increased to 9.4 hours and the alum cut down to 1.4 grains per gallon. During March even shorter runs have occurred. At Evanston short runs were also experienced during the first few months of operation but these have gradually increased so that now runs from 20 to 80 hours are common as follows:

MONTH OF OPERATION	LENGTH OF RUN
	hours
First	3.8
Second	5.3
Third	8.3
Fourth	7.3
January, 1921	75.0
February, 1921	75.0

It is only necessary to add the labor schedule at the plants so that you may have it for comparative purposes. At East Chicago there is one superintendent, one chemist and three operators, a total of five. At the Whiting plant, where the plant is combined with a high lift pumping station (the first floor is the high lift pumping station, comprising four electrically driven pumps), there is a superintendent and in addition two men on each shift. At the Evanston plant there is a superintendent and one man on each shift. At Evanston and East Chicago the superintendents also look after the high lift pumps. The short operation of these plants has somewhat limited the available data.

TABLE 2

Operating data for water filtration plants along Lake Michigan near Chicago

	DECEMBER, 1920			JANUARY, 1921			FEBRUARY, 1921			MARCH, 1921			APRIL, 1921		
	Evanston	Whiting	East Chicago	Evanston	Whiting	East Chicago	Evanston	Whiting	East Chicago	Evanston	Whiting	East Chicago	Evanston	Whiting	East Chicago
Average quantity filtered M.G.D.	4.6		10.4	4.5	4.0	10.4	4.8	3.9	8.7	5.2	3.8	8.1	5.8	3.7	7.5
Per cent capacity	38.0		130.0	37.0	100.0	130.0	40.0	98.0	109.0	43.0	95.0	101.0	48.5	94.0	94.0
Average runs, hours	87.2		4.4	74.9	8.0	3.6	77.0	9.4	6.2	32.7	7.3	7.4	20.3	4.8	7.7
Maximum runs, hours	144.0		13.0	144.0	15.0	10.2	144.0	19.2	1.7	47.7	15.0	15.0	59.5	7.2	17.7
Minimum runs, hours	28.3		0.5	14.1	4.0	1.0	28.0	4.1	16.8	12.9	4.2	2.5	7.4	3.1	1.3
Wash water, per cent	1.2		16.7	1.6		11.1	1.3	5.9	7.8	2.5	5.9	5.7	2.6	8.4	5.2
Alum, G.P.G.	0.7		0.6	0.7	1.5	1.2	0.7	1.4	2.0	0.7	1.4	1.9	0.7	1.6	2.2
Lime, G.P.G.			0		0.7	0		1.0	0		1.1	0		1.2	

DISCUSSION

A MEMBER: Was the aeration effective in removing the odors, or the taste, rather?

MR. GREELEY: That is a question that is rather difficult to answer completely because of the complexity of the odors that we get. There appears to be a difference in the petroleum and the coal-tar tastes. There is a substantial improvement due to aeration. You can smell the taste coming off the aeration basin and the filtered water has what may be called a cistern taste, or a flat taste. When we were operating the testing station, we had to taste the water treated. There was no chemical means for determining the taste and there was a substantial agreement that the taste was removed. At the present time, with winds which apparently restrict the pollution to the petroleum odor there is substantial removal. The removal of water carrying a medicinal taste may be different. It is not possible to tell more until we have gone through different seasons and have a more consecutive tabulation of data under different conditions. A plant of four months age has not yet reached its optimum of operation.

DR. BARTOW: Have any analyses been made to show the difference in the water at Whiting and East Chicago? It might be possible to determine the difference in hydrogen ion concentrations.

MR. GREELEY: There are not nearly enough of those data available yet. We have been taking the matter up with the various industries. We want to get the data over seasons and under wind conditions, so that the factors affecting the problem as a whole can be properly related to each other.

REPORT OF THE FINANCE COMMITTEE FOR THE FISCAL YEAR ENDING MARCH 31, 1921

The Finance Committee present the following report on the financial operations of the Association for the fiscal year ending March 31, 1921.

We have audited the books of the Secretary and Treasurer and found them correct. We have examined and verified all vouchers. The respective reports of the Secretary and Treasurer set forth the details of the financial affairs of the Association, and are in accordance with their books.

OPERATING INCOME AND EXPENSE

In past years it has been the uniform custom of this and other Finance Committees, to use as the basis for figuring annual budgets the bank statement of the Treasurer. This practice is liable to mislead because, precisely speaking, neither the income nor the expense of the Association is therein correctly reported. There are accommodation receipts and expenses balancing each other which swell the total receipts and expenses reported by the Treasurer. For example, reprints of author's papers, binding cases, etc., represent initial outlays which later are returned.

Your committee has examined and audited the books of the Treasurer and the Secretary, and as before stated has found them to be correct, and their cash balances to agree. For the reasons just stated, however, the operating income and expense of the Association, as reported by the Treasurer and the Secretary do not agree. The actual figures, eliminating compensating expenses and repayments, are given in the Secretary's report, and will be used hereafter in this report.

The budget allowance recommended by the Finance Committee and approved by the Montreal Convention to cover the operating expenses of the fiscal year 1920–21 totaled \$15,350, and of this the net sum of \$15,136.12 was expended on the year's operations. The operating income, as shown in the report of the Secretary was \$13,128.40. The net deficit on the year's operations was \$2,007.72.

On April 1, 1920, at the beginning of the last fiscal year, the cash balance on hand in bank was $2,392.52. At the close of the year it was $234.74 showing a reduction of $2,157.78. The net deficit being $2,007.72, the difference, or $150.06, is explainable by the fact that certain expenditures were made, as usual, by the Secretary's office for binding cases, etc., that are carried on the merchandise account. These items are not charged into profit and loss accounts as they represent stock on hand.

Summarized statement of accounts for the fiscal year ending March 31, 1921

Balance on hand in bank, April 1, 1920	$2,392.52	
Net income from all sources	13,128.40	
Total income		$15,520.92
Total operating expenses		15,136.12
		$384.80
Disbursements for merchandise, now on hand		150.06
Balance on hand in bank, April 1, 1921		$234.74

PERMANENT INVESTMENT FUND

There are now in the hands of the Treasurer, by authority granted the Finance Committee by the Executive Committee, certificates constituting the Permanent Investment Fund of the Association as follows:

	Par value	*Market value June 1, 1921*
Four $1000 Dom. Can. 5% Bonds due Apr. 1931	$4,000	$3,520.00
Four $500 U. S. 1st Liberty Loan Bonds 3½%	2,000	1,750.00
One $1000 U. S. 2nd Liberty Loan Bond 4¼%	1,000	870.00
Two $1000 U. S. 3rd Liberty Loan Bonds 4¼%	2,000	1,811.20
Two $1000 U. S. 4th Liberty Loan Bonds 4¼%	2,000	1,741.20
One $1000 U. S. Victory Loan Bond 4¾%	1,000	980.60
Total	$12,000	$10,673.00

BUDGET ALLOWANCES AND DISBURSEMENTS, 1920–21

While last year's budget total was sufficient to cover all needs, the allowances for some items were too small, and for one item, committee expenses, too large. Convention expenses exceeded the allowance by $261.47. Section expenses overran the budget by $117.84. The cost of printing the JOURNAL exceeded the allow-

ance by $583.96. On the other hand, since there were no special meetings of the Executive Committee, the allowance for committee expenses was underrun by $1,040.13.

When it was seen that the allowances for certain items in the budget surely would be more than wiped out by the necessary expenditures under those items the Executive Committee, as provided for in the Constitution, voted the transfer of funds from other items with the stipulation that the total budget allowance voted by the Montreal Convention should not be exceeded.

Following is a statement of the budget allowances and disbursements for the past fiscal year:

	Budget	*Disbursements*
Convention expenses	$700.00	$961.47
Office expenses	1,000.00	1,004.98
Committee expenses	1,200.00	158.87
Section expenses	600.00	717.84
Insurance	75.00	62.00
Salary of Secretary	500.00	500.00
Salary of Ass't to Sec'y	1,200.00	1,200.00
Salary of Editor	1,200.00	1,200.00
Printing of JOURNAL	7,500.00	8,083.96
Office rent	1,080.00	1,080.00
Contingencies	295.00	167.00
Totals	$15,350.00	$15,136.12

EXTRAORDINARY EXPENSES FOR THE NEXT FISCAL YEAR

Last year the formation of a Council on Standardization was authorized by the Montreal Convention. The work of this Council bids fair to raise the usefulness of the Association to a far higher plane than it ever occupied before. The past year has been devoted to organization of the various committees designed to function under the Council. This year Committee work will commence in earnest. We have discussed the financial needs of the Council with its Chairman, and in the budget (Committee Expenses) are including $2,000 for this work. We realize that this sum is far below the amount of money which the Council could use to advantage, nevertheless in recommending its approval we realize that, if it is all used, it probably will be necessary to draw upon our permanent investment fund, as our income for next year, even with the increased dues, will not meet the expenses of the Association when this new, but we believe highly necessary, item is added. We express the

hope, therefore, that only so much of the $2,000 will be used by the Council on Standardization as will be productive of commensurate results.

It seems inevitable that we must face also an increase in operating expenses in a number of other items this year. Convention expenses appear to be steadily increasing. Office expenses, if therein is directed a much needed campaign for new members, will easily run into $1200, or $200 over last year's expenditures under this item. A more liberal allowance for section expenses is demanded, and a creditable JOURNAL cannot be produced at prevailing charges for stock and printing for less than $8,000.

The Editor suggests that the editorial work of his department is worth $900, a reduction of $300 in his present salary. Your Committee is pleased to rely upon his judgment in this regard, but recommends that the $300 thus saved be added to the Secretary's salary, making it $800 instead of $500 as at present. This would make the salary cost of the Secretary's office for a full time Secretary and Assistant to the Secretary but $2000, and if such service if worth anything it is worth that.

ESTIMATED INCOME FOR THE FISCAL YEAR, 1921–22

In view of the almost unavoidable increased operating expense of this year, and when serious consideration is being given to expanded activities calculated to make the Association a bigger and better agency for the promotion of water works affairs, it is well at this time to analyze our resources. We have discussed this question among ourselves and necessarily have taken counsel with the Secretary. As a result we have estimated that the net income for the current fiscal year will be as follows, basing our figures on the membership lists as of April 1, 1921:

1286 active members at $7.00	$9,000	
104 corporate members at $10.00	1,040	
147 associate members at $15.00	2,205	
Total from annual dues	$12,245	
Estimated initiation fees	$1,000	
Estimated income from advertisements in JOURNAL	2,500	
Interest on investments and deposits	500	
Miscellaneous	500	
Total	$4,500	
Estimated Grand Total Income		$16,745

RECOMMENDED BUDGET FOR THE YEAR 1921–1922

In view of all the foregoing your Committee recommends the following budget to cover the operating expenses of the Association during the current fiscal year:

Convention expenses	$800
Office expenses	1,200
Committee expenses	2,800
Section expenses	900
Insurance	75
Salary of Secretary	800
Salary of Ass't to Sec'y	1,200
Salary of Editor	900
Printing of JOURNAL	8,000
Office rent	1,080
Contingencies	245
Total	$18,000

As had been set forth above we estimate the net income of the Association during the current year at a total of $16,745. The foregoing budget calls for $1255 in excess of this figure. A strenuous but inexpensive campaign for new members which would bring in over and above out present anticipations 70 active members, 10 corporate, and 10 associate members would, in initiation fees and one year's dues, account for the deficiency above stated. Failing to accomplish the required end in this most desirable fashion expenditures outside of salaries and rent must be cut all along the line or else we must draw upon our investment fund. Rather than that the useful work of the Association should be curtailed through lack of sufficient funds your Committee would prefer withdrawals from our surplus. Nevertheless it has taken many years to build up this fund which is the kind of money all too easily and thoughtlessly spent when once a start is made, and your Committee hopes that special effort will be made by all classes of membership to bring in new members. It is the only right way to finance the growing activities of the Association.

In recommending a budget this year in sum total exceeding the anticipated income, your Committee desires to state that it does so primarily to care for the apparent needs of the Association during the next year, after which it is hoped that increased membership and increased dues will suffice to meet all financial requirements of the Association.

The Treasurer's report shows a balance of $950.55 in the Electrolysis Investigation Fund.

The Treasurer is under bond for $10,000 in accordance with the order of the Executive Committee, and this bond is in the custody of the Chairman of the Finance Committee.

In conclusion, your Committee strongly recommends that the principle of transferring funds from one budget item to another, upon which there has been an unexpected drain, be approved. It is impossible to estimate many of the real needs under some of the items a year in advance, and the work of the Association should not be crippled by rigid adherence to the budget which is actually not passed upon until months after it should be to become a business like financial procedure. The Publication Committee has to print the March and May Journals and send the July Journal to the printer before the budget covering such work is made up; thus it is readily seen that the Committee is badly handicapped by present methods.

George A. Johnson,
Chairman,
J. Walter Ackerman,
George C. Andrews.

Addendum. The Chairman of your Finance Committee, after four years' service, has requested the incoming President to relieve him of his duties. He does this regretfully because of the uniformly pleasant associations during his entire tenure of office, but believes that four years is long enough for any one man to hold down such a job. His best wishes, mingled with a considerable feeling of sympathy, are extended to his successor.

George A. Johnson.

ANNUAL REPORT OF THE PUBLICATION COMMITTEE

The last Publication Committee stated in its annual report that in case there were any further advances made during the 1920–1921 fiscal year of the Association, the proposed appropriation for the Journal would be insufficient to bring out six numbers. This statement is printed on page 629 of the Journal for July, 1920. At the time the report was prepared, the old Committee had already sent to press three large numbers of the Journal, to be charged against the 1920–1921 budget appropriation. The Association does not make up its budget at the beginning of the fiscal year, but after the year has well advanced, something that is probably unique in financial affairs.

The result of this peculiar condition has been a deficit in the printing allowance for the current year. After the last committee's report had been written, the cost of typesetting was advanced about $33\frac{1}{3}$ per cent and the cost of paper and presswork about $38\frac{1}{2}$ per cent. The Publication Committee asked the Finance Committee to decide whether to give up an attempt to issue six numbers or to print three small numbers during the rest of the fiscal year and rely upon some assistance from unexpended balances in other budget items to make up the inevitable deficit, which was foretold by the last Publication Committee but not provided for in the budget. As the Association had accepted advertising contracts based on six numbers of the Journal per year, it was finally decided to issue the six numbers. Furthermore, the issues of March, May and July, 1921, which are charged against the budget submitted at this convention, have been kept small in order that the next Publication Committee need not start its work with a deficit certain to complicate its work.

During the years that some of the members of this Committee have been connected with the publication of the Journal the leading items of printing expenses have been increased from 78 to 82 per cent while the budget appropriation has been increased but 35 per cent. The difference has been met to some extent by rewriting parts of the papers, rearranging tables and preparing drawings for photoengraving in such ways as to save considerable money over the cost of printing the same matter in the form submitted by the authors. In spite of the savings thus made, it has been necessary during the last six months to drop all of those features of the Journal

which were previously undertaken in an attempt to make it more than a mere filing case for Association and Section papers.

Aside from this financial aspect of the Committee's work, its most unsatisfactory feature has been the very small amount of information of particular value to the operator of the water works in our cities of small and medium size. The Committee feels that the Association's best work lies in helping this class of members, who are called upon to settle a wide range of problems, without consulting assistance in most cases. This problem has been close to the Committee's thoughts during the year and has been discussed often yet the Committee is dissatisfied with what it has accomplished in this direction. The Committee has already communicated its opinions on this subject informally to the President-elect.

The members of this Committee who have served for several years, including the Editor, feel that the time has come when new men with new ideas should take their place in developing the JOURNAL. An Association like this must move forward all the time, and progress is most certain in an organization of national scope when there is rotation in office in the important committees of an executive nature. The members of this Committee who have been serving in this capacity for some time desire in bringing their work to an end to record their appreciation of the many courtesies received from the officers of the Association and its Sections and from many individual members. Without such help they could not have carried the JOURNAL along through the period of the war and the succeeding years of high prices, when many society publications were curtailed greatly or dropped entirely. The Committee feels that the period of high prices is passing and it confidently expects a reduction will be made in printing charges during the year.

WILLIAM W. BRUSH,
Chairman.
GEORGE A. JOHNSON,
A. W. CUDDEBACK,
G. C. HABERMEYER,
JOHN M. GOODELL,
Editor.

REPORT OF SECRETARY FOR FISCAL YEAR 1920–21

Financial statements are submitted on separate sheets, consisting of: Financial Statement, Operating Statement and Trial Balance.

The trial balance is included to show in detail the payments to the several Sections and the different Committees, as these are all bunched in the Budget Accounts in the other statements.

It was necessary during the year to transfer some of the Budget Accounts from one account to another, as some were found insufficient. However, the total Budget appropriations were not exceeded.

During the fiscal year the net loss from exchange on checks amounted to $25.57, due largely to payment by dues of Canadian members in Canada money. This item was at the close of the year charged as an office expense. During most of last year sterling was paid here at par, for the next year there will be a considerable discount in this and all foreign currency.

During the year two questions were submitted to the Executive Committee by letter:

(1) For an allowance of not over $200 for the expenses of Robert E. Horton as our representative on the Advisory Council of the National Mapping Board. Mr. Horton had also taken this up direct with President Little, who declined to allow the expense. For this reason Mr. Little objected to having the question submitted to the Committee so it was dropped, though seven members of the committee had voted to make the allowance.

(2) For the transfer of Budget Accounts. This was approved by a vote of 11 to 3, all members voting.

MEMBERSHIP

No general circular was sent to unrepresented water works this year, partly on account of lack of funds and partly for the want of a reliable address list. When a list was finally secured it was too near convention time to send it out; the rush of convention work was on.

The usual office work, plus the splendid work of Mr. Leisen, resulted in the receipt of the largest number of new members on record 262. The losses, however, have been heavy, as shown by

the detail report, so the net gain was only 118, which number has been twice exceeded.

There is no special explanation for the large number dropped for nonpayment of dues; they come from all shades of membership. Bills were sent as usual before the beginning of the fiscal year. In July a notice was sent with a duplicate of the bill and statement that the JOURNAL would not be sent to those who had not paid their dues, and all such were taken from the addressing machine, being replaced as they paid their dues and back numbers of the JOURNAL sent to them. The third notice was in the shape of a signed form letter and the fourth a personal letter. Ninety-eight of the last were sent, with a self-addressed stamped envelope for a reply. Eighteen paid, four sent resignations and the other 76 paid no attention. Bills for the ensuing year were sent with a statement of the arrears. (Seven have since paid and been restored, May 25, 1921.)

MEMBERSHIP STATEMENT

April 1, 1920	1177	107	133	5	1422
Received during year	232	6	23	0	261
Restored during year	9	1			10
Transferred to other classes	2	1			
	1420	116	156	5	1693
Losses during year	134	11	9	2	153
Roll April 1, 1921	1286	104	147	3	1540

Detail of losses

Active	8	42	83	1
Corporate		2	7	2
Associate		8	1	
Honorary	2			
Totals	10	52	91	3

Gain

Active		109
Associate		14
		123

Loss

Corporate	3	
Honorary	2	5
Net gain		118

FINANCIAL STATEMENT

Cash on hand April 1, 1920		$2,388.56
Receipts:		
Initiation fees		1,220.00
Annual dues		8,261.00
Authors copies, profits from		3.34
Interest on invested funds		530.00
Subscriptions to JOURNAL		420.00
Advertisements in JOURNAL		2,490.65
Sales of PROCEEDINGS		20.00
Sales of JOURNAL		59.25
Interest on bank deposits		80.45
Typhoid Toll. Sales of reprints		.50
Hydrant and Valve Specifications		1.75
Depreciation Committee Report, sales of		2.00
Pipe Specifications, sales of		39.46
		$15,516.96
Disbursements:		
Office expenses	$1266.36	
Binding cases	146.10	
Convention expenses	700.00	
Printing and distributing JOURNAL	8083.96	
Committee expenses	158.87	
Salary of assistant to the secretary	1200.00	
Salary of secretary	500.00	
Rent of office	1080.00	
Insurance, fire and liability	62.00	
Salary of editor	1200.00	
Contingent expenses	167.09	
Section expenses	717.84	15,282.22
Balance, cash on hand April 1, 1921		$234.74

OPERATING STATEMENT

Operating expenses:	
Office expenses	$1,266.36
Convention expenses	700.00
Printing and distributing JOURNAL	8,083.96
Committee expenses	158.87
Salary of assistant to the secretary	1,200.00
Salary of secretary	500.00
Rent of office	1,080.00
Insurance, fire and liability	62.00
Salary of editor	1,200.00
Contingent expenses	167.09
Section expenses	717.84
Total operating expenses	$15,136.12

Operating income:

Initiation fees	$1,220.00	
Annual dues	8,261.00	
Authors copies, profits from	3.34	
Interest on invested funds	530.00	
Subscriptions to JOURNAL	420.00	
Advertisements in JOURNAL	2,490.65	
Sales of PROCEEDINGS	20.00	
Sales of JOURNALS	59.25	
Interest on bank deposits	80.45	
Typhoid Toll. Sales of reprints	.50	
Hydrant and Valve Specifications	1.75	
Depreciation Committee Report, sales	2.00	
Pipe Specifications, sales of	39.46	13,128.40
Net loss from operation		$2,007.72

These figures are made up without regard to balances, or to disbursements other than for operation. They show the NET income and operating expenses giving the cost of operation above income for the year. $146.10 paid for binding cases, which will be paid for by members during the year and not shown here.

TRIAL BALANCE, MARCH 31, 1921

Initiation fees		$1,120.00
Annual dues		8,261.00
Authors copies		3.34
Office expenses	$1,240.79	
Interest on investments		530.00
1920 binding cases	128.65	
1917 binding cases	19.67	
1918 binding cases	44.18	
1919 binding cases	64.44	
Subscriptions to JOURNAL		420.00
Advertisements in JOURNAL		2,490.65
Sale of PROCEEDINGS		20.00
Exchange on checks	25.57	
Sale of JOURNAL		59.25
Convention expenses	700.00	
Interest on deposits		80.45
Typhoid Toll		.50
Printing JOURNAL	8,083.96	
Salary of assistant to the secretary	1,200.00	
Salary of secretary	500.00	
Rent of office	1,080.00	
Insurance	62.00	
Salary of Editor	1,200.00	
Illinois Section	97.25	

New York Section	124.81	
Iowa Section	75.21	
Minnesota Section	58.29	
Central States Section	150.00	
Canada Section	146.63	
Chemical and Bacteriological Section	65.65	
Equipment, typewriter, etc	108.40	
Profit and loss		14,552.80
Hydrant and Valve Specifications		1.75
Investments	11,945.00	
Contingencies	167.09	
Depreciation Committee Report		2.00
Executive Committee	54.00	
Membership Committee	12.30	
Finance Committee	13.05	
Convention Committee	67.82	
Publication Committee	11.70	
Pipe Specifications		39.46
Balance cash on hand	234.74	
	$27,681.20	$27,681.20

J. M. DIVEN,
Secretary.

SOCIETY AFFAIRS

ADDITIONS TO THE MEMBERSHIP

Active

J. C. Adams, American Water Works & Electric Company, 50 Broad Street, New York, N.Y.

M. Harvey Bliven, Assistant Engineer Water Department, Eastman Kodak Company, 5 Adrian Street, Rochester, N.Y.

R. E. Borrowman, Bradley Engineering Service, St. Cloud, Minn.

A. C. Bromschwig, Superintendent Filtration and Water Works, Whiting, Ind.

J. W. Calhoun, Meter Foreman, New Chester Water Co., Box 264, Chester, Pa.

Howard B. Claflin, Superintendent Water Works, City Hall, Phoenix, Ariz.

Oscar Claussen, Chief Engineer Department of Public Works, City Hall, St. Paul, Minn.

H. Conradi, State River and Water Supply Commission, Treasury Gardens, Melbourne, Australia.

Ivan Escott, Assistant General Inspector, Home Insurance Company, 56 Cedar Street, New York, N.Y.

G. E. Flower, Sanitary Engineer, Room 211 City Hall, Cleveland, Ohio.

W. M. Heaton, Treasurer Pueblo Water Works, Pueblo, Colo.

Albert H. Jewell, Chief Engineer, State Board of Health, 1636 New Hampshire Street, Lawrence, Kans.

Arnott Chiswell King, Chief, Meter Department, Massillon Water Supply Company, Massillon, Ohio.

Frank T. Lamey, Superintendent, New Chester Water Company, 422 East 20th Street, Chester, Pa.

E. A Lawrence, Consulting Civil and Municipal Engineer, 511–12 Hartman Building, Columbus, Ohio.

John A. McDace, Water and Sewer Contractor, 4036 Fairview Avenue, Detroit, Mich.

Frank M. McElroy, Superintendent Water Department, 321 Main Street, Racine, Wis.

R. F. MacDowell, Division Engineer, Morris Knowles, Inc., 716 Hippodrome Building, Cleveland, O.

Joseph F. Majeske, Assistant Cashier, Board of Water Commissioners, Detroit, Mich.

L. A. Marshall. Chemist, Filtration Plant, W. 32d Street and Detroit Ave., Cleveland, O.

William A. Megraw, Water Engineer, City Hall, Baltimore, Md.

H. E. Miller, Director, Bureau of Sanitary Engineering, State Board of Health, Raleigh, N. C.

Harry Reinhardt, Assistant Chief Engineer, East Bay Water Company, Oakland, Cal.

Orville Z. Tyler, Superintendent Water and Power, Main and Orange Streets, Jacksonville, Fla.

Edwin B. Wagner, Superintendent Water Works, Downington, Pa.

Corporate

Department of Water, Oswego, N. Y.

Sherrill-Kenwood Water Commission, Stephen R. Leonard, Chairman, Kenwood, N. Y.

Water Trustees, Muscatine, Ia.

Associate

American Iron Products Company, Inc., 107 Liberty Street, New York, N. Y.

Continental Pipe Manufacturing Company, 3904 Woolworth Building, New York, N. Y.

National Tube Company, W. L. Schaeffer, 1902 Frick Building, Pittsburgh, Pa.

Underwood Typewriter Company, 30 Vesey Street, New York, N. Y.

The J. G. White Engineering Corporation, 43 Exchange Place, New York, N. Y.

Deaths

H. C. Curran, Superintendent Water Works, Waterford, N. Y., died May 7, 1921.

Albert H. Wehr, June, 1921.